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ABSTRACT

This report is presented in four parts: (1) Research Results and Their Application; (2) Manpower, Training and Public Involvements; (3) OWRR Activities; (4) Highlight Reports by the 51 State Institute Directors. Part 1 reviews the results expected to be forthcoming through projects financed during the Calendar Year 1969. This section focuses on 12 water related problem areas, including such problems as improvement of water resource systems, heated water discharge, sediment, water quality, water supply and demand, water-caused damages, water planning and ecology, metropolitan water systems, information dissemination, and others. Part 2 discusses the contributions to training, the production of reports and publications, and dissemination of information during 1969. The various activities of the Office of Water Resources Research (OWRR) are considered in Part 3. The final section reviews for each state its water problems and related research, possible future program directions, and academic and public involvement. The 19 appendices provide listings of projects, funding, allocations, research, references, associated colleges and universities, and other useful information. (PR)

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COOPERATIVE WATER RESOURCES RESEARCH AND TRAINING

1969 annual report

UNITED STATES DEPARTMENT OF THE INTERIOR
OFFICE OF WATER RESOURCES RESEARCH
Washington, D.C. 20240

March 3, 1849

SE 010 037

"As the Nation's principal conservation agency, the Department of the Interior has basic responsibilities for water, fish, wildlife, mineral, land, park, and recreational resources. Indian and Territorial affairs are other major concerns of America's 'Department of Natural Resources.'

"The Department works to assure the wisest choice in managing all our resources so each will make its full contribution to a better United States--now and in the future."

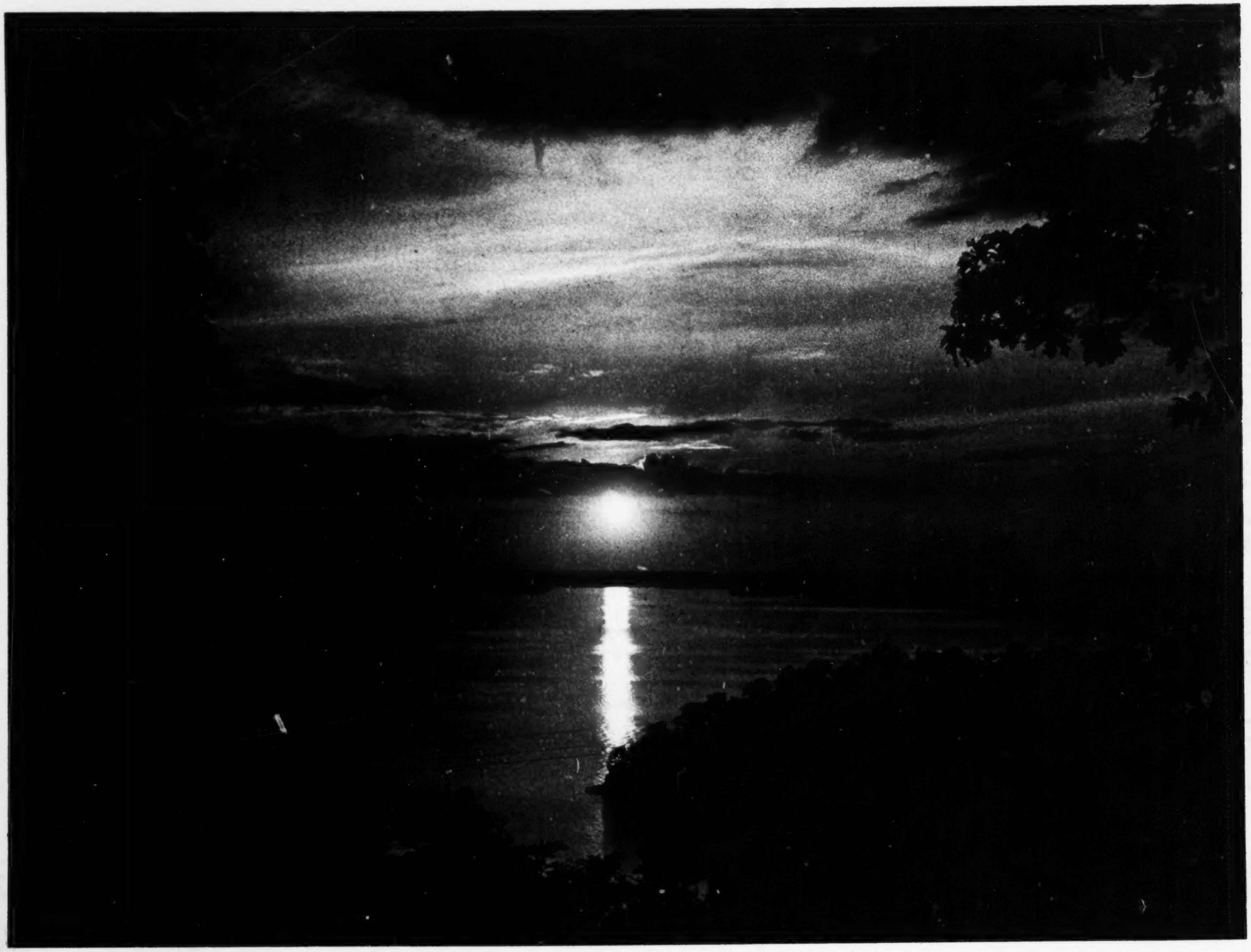
ED0 43527

COOPERATIVE WATER RESOURCES
RESEARCH AND TRAINING

1969 ANNUAL REPORT
Pursuant to
THE WATER RESOURCES RESEARCH ACT OF 1964
As Amended by Public Law 89-404

UNITED STATES DEPARTMENT OF THE INTERIOR
Office of Water Resources Research
Washington , D.C. 20240

December 1969



Water—clean water in abundance—is more than an essential for existence; when occurring in a situation like this in the Ozarks, it contributes to a more peaceful world.

Photo by Walker Missouri Tourism

PREFACE

This is the fifth annual report of the program authorized by, and conducted in accordance with, the Water Resources Research Act as amended. The report is responsive to the reporting requirements of the Act and the Rules and Regulations developed to assist in administering the Act. Items of required information are underlined in the following paragraphs for ready identification, and page numbers or sections of the report in which they appear, are listed.

Disposition during the preceding calendar year (1969) of moneys appropriated to carry out the Act is discussed, beginning on page 112, and shown in Appendices G, H, I, J, and L. Fiscal Year 1969 annual allotments, grants, contract awards, and disbursements are shown in Appendices A to E, and the status of funds appropriated in prior fiscal years, in Appendix F.

Results expected to be accomplished through projects financed during Calendar Year 1969 are discussed by water problem areas in Part I. The first 10 of the 12 problem areas described in the account of "Research Results and Their Application" are condensations of statements from a draft report of the Committee on Water Resources Research, Federal Council for Science and Technology (FCST). The eleventh and twelfth problem areas were added to encompass those P.L. 88-379-supported projects which did not fit in any of the 10 categories. The allocation of water research funds appropriated under the Act is shown by problem area, in Figure 1, and by FCST research categories, in Figure 2. The FCST research categories are described in Appendix M.

Conclusions reached in, or other results achieved by, research projects completed in 1969 are described in Part I with respect to research; and, in Part II, contributions to training and the production of reports and publications and the dissemination of information are discussed.

An account of the work of all institutes financed under Section 100 of the Act is given in Part IV. This Part, composed of a highlights statement by each State institute approved under the Act, supplements Parts I and II.

A statement indicating that no portion of an allotment to any State has been withheld appears on page112, paragraph 5.

The comments and recommendations of the 1969 Special Advisory Panel relative to the needs and problems of the overall program are included as pages xv to xx of this report. Comments and advice expressed by the State institutes with respect to problems in administering the program are given in Part III.

Part III is an account of the activities of the Office of Water Resources Research (OWRR) in administering the program at the Federal level for the Department of the Interior. OWRR acknowledges with thanks and appreciation, (1) the helpful advice of the Special Advisory Panel mentioned in the previous paragraph which is convened annually in accordance with the Rules and Regulations; (2) the work of consultants employed to provide critical reviews or state-of-the-art reports on selected problem areas; (3) the valuable assistance of many Federal agencies, both within and outside of the Interior Department, on the review of research proposals; (4) the outstanding response of participating universities to the needs for improved research and training in the water resources field; (5) State agencies which are providing increased support for research and cooperating in many other ways; (6) the demonstrated desire and competence of private industry and non-academic research firms to assist in solving water problems through participation in Title II research and serving on advisory panels; (7) the leadership of the 51 State institute directors and their university colleagues who have developed effective water centers responsive to local, State and regional needs and have submitted high quality annual reports on which to base the present report; and (8) the demonstrated interest of the Congress, the Executive Office of the President, and the general public without whose support this cooperative Federal-State research and training program could not have been launched so successfully.

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1969 ANNUAL REPORT

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UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF WATER RESOURCES RESEARCH
WASHINGTON, D. C. 20240

Memorandum

To: Secretary of the Interior
Through: Assistant Secretary for Water Quality and Research, and Under Secretary

From: Director, Office of Water Resources Research

Subject: Annual Report--Office of Water Resources Research

Submitted herewith is a report of activities and accomplishments for 1969 in accordance with the regulations for administering the Water Resources Research Act of 1964 (18 CFR 506.5) and Section 307 of P.L. 89-404 (80 Stat. 130) dated April 19, 1966.

I was privileged to become acquainted with this cooperative research and training program as a member of the 1967 Special Advisory Panel, convened in accordance with the Act. Now, as Director of the Office of Water Resources Research, I can state with a measure of pride that continued progress has been made in achieving the major objectives of the Act, "to assist in assuring the Nation at all times of a supply of water sufficient in quantity and quality to meet the requirements of its expanding population ...." The program has become widely recognized since its inception five years ago for its contributions in research and training, information exchange, and, at State and local levels, public and academic involvement in water resources planning and management.

Pursuant to reporting requirements, we have included, in the report, advice and recommendations of the 1969 Special Advisory Panel relative to the overall program, examples of research results, expected results and other accomplishments, and a statement that all funds appropriated for allotments and grants have been made available to the State water resources research institutes--none having been withheld for any reason.

I recommend that this document be adopted as your report to the President and to Congress as required by the Water Resources Research Act of 1964 as amended.

H G Hershey
H. G. Hershey

Approved and adopted as the report
of the Secretary of the Interior

DEC 17 1969

Russell E. Train
Acting Secretary of the Interior

Enclosure

SUMMARY AND CONCLUSIONS

Program Objectives

Although, in its fifth year of support, the Federal funding level remained approximately the same as in Fiscal Year 1968, continued progress was made in furthering the major program objectives "to stimulate, sponsor, provide for, and supplement present programs for the conduct of research, investigations, experiments, and the training of scientists in the fields of water and of resources which affect water." Significant advances were made, also, in promoting water resources scientific information exchange, technology transfer, research coordination, and public education.

Number of Participating Institutions and Organizations

Highlights of this nation-wide, cooperative Federal-State research and training program at the State level are given in Part IV of this report. These are in the form of brief individual statements of the directors of the 51 State water resources research institutes approved under the Act. These institutes or centers, located at a State university in each State and Puerto Rico, serve as focal points in administering the program. Participation of other universities and institutions, non-academic or industrial research firms, and private or public research entities is encouraged, however, and, in Fiscal Year 1969, approximately 800 research projects were being carried out by 132 colleges and universities, 19 private or commercial research firms, 2 non-profit organizations, and 4 public agencies at State and local levels.

Examples of Application of Research Results

After 5 years of support for Title I research, most of the State institute directors -- and many of the Title II research grantees or contractors after only 2 years -- were able to cite examples of the application of research results from P.L. 88-379-supported projects. These are included in Parts I and IV of the report, but may be illustrated by the following:

* An Alabama project (B-007-ALA) has received world-wide recognition for information on hydrology of limestone terranes and for preparation of an annotated bibliography of over 2000 references. This bibliography will be distributed as part of the program of the International Hydrologic Decade.

* A report on heat losses in circulating water distribution systems in subartic Alaska is reported to be required reading for all U.S. Public Health Service engineers upon their arrival in the State.

* Results of project A-008-ARK, concerned with digital systems for on-site data collection for water quality analysis, have assisted the U.S. Fish and Wildlife Service in fish hatchery operations involving the measurement and control of oxygen in water.

* Results of project B-001-CAL, dealing with optimization for power generation, peaking power, and water releases from the many storage reservoirs involved in the California Water Plan, have been directly used by the State in its planning.

* Extensive application of stream bank stability criteria developed in projects A-002-COLO and B-014-COLO has been made in planning highway construction through the Rocky Mountains to prevent erosion and sediment pollution.

* Project B-006-IDA has developed information being used by the State Reclamation Engineer in Idaho to establish reasonable levels of pumping lift in administration of ground water laws.

* As a result of project A-008-IND which showed a critical shortage in Indiana of manpower for water resources positions, a new associate degree curriculum was developed for the training of technicians.

* Data from projects A-022 and 023-MICH, indicating that streams entering Lake Michigan from the Lower Peninsula of Michigan contribute over 11,000 pounds of phosphorus per day, were used by the State regulatory agency in a decision to require 80 percent removal of phosphorus from sewage effluent by municipalities in the Lake Michigan drainage basin by 1972.

* New Jersey studies have determined the operating effectiveness and costs of instream aeration systems. The studies indicated that when applied to the Passaic River, New Jersey, an aeration system which would cost $194,000 annually would be as effective in raising dissolved oxygen levels as advanced waste treatment estimated to cost $785,000 annually.

* Telemetry developments under project A-002-UTAH are being used in operational programs by the U.S. Department of Agriculture.

* The Tri-State Transportation Commission in New York City notified OWRR that results of a Title II project (C-1114), conducted by personnel of Barnard College of Columbia University, had immediate application to the long-range water supply and sewerage plan for the Tri-State Region of New York, New Jersey and Connecticut.

* Use of water reservoirs in urban areas for flood control, with projected multiple-use benefits of water conservation, reduced costs and multi-use reservoir benefits was the subject of project C-1187 conducted by North American Rockwell Corporation. Actual economic, engineering and benefits data from Santa Maria, California, were used in the evaluations. A number of urban areas have shown considerable interest in this water reservoir approach to flood control and further application of a demonstration project is being developed by the city of Santa Maria.

Seed Money Effects

These research results are being produced by both applied and fundamental, short-term and long-term projects. Non-Federal funds or the equivalent are used for supplementing or matching Federal funds in all Title I projects and in many Title II projects. Many projects, initiated with modest seed-money funding from OWRR, have shown such promise that additional support from other Federal or non-Federal agencies has been secured to mount more extensive and significant investigations. For example, the Montana Center director reports that with OWRR funding not exceeding over $10,200 in any fiscal year since project A-007-MONT, dealing with mountain precipitation and distribution, was started on July 1, 1966, three associated grants and contracts were generated involving nearly $1.2 million support from the Bureau of Reclamation, National Science Foundation and the U.S. Army.

Manpower

Nearly 1200 professional investigators and 1862 student research assistants from dozens of scientific and engineering disciplines were engaged in research on Title I projects during 1968-69. Engineers, biologists, economists, and geologists were most numerous, but there was need in some of the projects for anthropologists, landscape architects and many others.

Of 215 professional investigators assigned to 57 Title projects, 118 were engineers, 24 were economists, and 15 were mathematicians, statisticians or computer specialists. This reflects the emphasis placed on water resources planning and systems analysis in the Title II program for 1969. Student assistants on Title II projects numbered 114. Thus, the ratio of professional investigators to student research assistants was 1:1.6 on Title I projects and 1:0.5 on Title II projects.

Examples were cited of 71 trained professional investigators from 28 scientific and engineering disciplines being attracted to the water resources field in the past year although previously they had not been engaged in water research or training. This brought new competence to the field and facilitated multidisciplinary research.

Research and Training Facilities

Universities participating in the P.L. 88-379 program have responded to the Nation's need for improved research and training facilities in the water resources field by employing over 1300 new staff members since 1965; adding nearly 1300 new water-related courses and constructing or acquiring new buildings, laboratories and other facilities yearly. During Fiscal Year 1969, 58 universities reported employing 238 staff members for new positions and 72 to replace employees who had retired, moved, or died. About 13 percent of the new employees were supported, in part, by P.L. 88-379 funds. New water-related courses reported by 61 participating universities in the 1968-69 school year numbered 286. Thirty-nine institutions in 32 States reported construction of, or major addition to 15 new buildings, completion of some 25 new laboratories, and construction or acquisition of 26 or more other major facilities.

Student Training

Formal student training is a function of the university and is not supported directly by OWRR. However, 1862 students served as research assistants on Title I projects during Fiscal Year 1969, and 114 students served in a like manner on Title II projects, making a total of 1976 receiving P.L. 88-379 financial support. Their work as research assistants under qualified principal investigators provided valuable experience. Nearly 4300 students in water-related training were reported to have benefited from the use of supplies and equipment purchased in connection with the research program.

Statistics on students enrolled in water-related curricula at universities are not readily available and there appear to be inconsistencies in reporting from year to year due to various interpretations of what constitutes a water resources student. The rapid increase in student enrollment reported in water-related fields between the 1964-65 school year and the 1966-67 school year appears to have slackened; yet, 4978 students were reported to have graduated in 1968-69 compared with 4513 in 1967-68. Over 13 percent of the graduates reported for school year 1968-69 had received P.L. 88-379 support as research assistants -- 8.1 percent of the bachelor, 19.0 percent of the master, and 26.8 percent of the doctoral graduates. Of approximately 60 percent of the graduates whose status was known following graduation, 47, 29 and 24 percent, respectively, obtained water-related positions, returned to school for further training, or went into military service.

Public Involvements

There is increased recognition on the part of State institute directors and other university staff members of the need for public involvements, as well as academic activities, and for improved means of transferring research results and technology to action agencies. Examples are given in Parts II and IV of this report. Many of the symposia, seminars and public meetings held contribute to student training as well as to public education.

During the year 1968-69, the Title I program produced 574 publications, 225 theses and dissertations, and 230 project completion reports; the Title II program produced 52 publications, 5 theses and 13 project completion reports. Availability of these publications and reports is described.

OWRR Activities

At the Federal level, the P.L. 88-379 program is administered by the Office of Water Resources Research. The OWRR staff of 37 with the cooperation of other Federal agencies, the academic community, and private firms and consultants knowledgeable in the water resources field, strives to facilitate the work of the State water resources research institutes and other participants, and, in other ways, carry out the objectives of the Act.

During the past year OWRR (a) sponsored the fourth annual water resources research and program coordinating conference; (b) contracted with consultants to prepare critical reviews or state-of-the-art reports on ecological considerations in water resources management, and a general assessment of systems engineering as applied to water resources; (c) held seminars on such subjects as systems analysis, dispersion of water pollutants, physical and mathematical models of estuaries, analysis of small watershed responses and soil water movement; (d) initiated a systems approach to Great Lakes research and (e) staff members participated in many intradepartmental and interdepartmental committees concerned with water resources planning, research and management.

Steps were taken to respond to the recommendations of the 1968 Special Advisory Panel and to develop a top-priority program of research on urban water resources problems. To implement this program, 36 Title II research projects were selected for support in Fiscal Year 1970 with emphasis on metropolitan water resources and systems analysis in water planning and management.

The OWRR-managed Water Resources Scientific Information Center (WRSIC) was enhanced by (a) expansion of the information base in machinable form; (b) improved user services in the form of selected water resources abstracts, indexes, and a limited selective dissemination information service; and (c) establishment of 3 additional centers of competence for abstracting water-related literature. Volume 4 of the Water Resources Research Catalog was published as a convenient means of informing researchers of current water resources studies and of keeping unproductive replication of research effort to a minimum.

With constant sharpening of focus on significant water problems and high priority research needs; increased awareness of, and attention to, dissemination of scientific information and the need for improved technology transfer; and its contributions to research coordination, and research and training capabilities as well as direct support of research in the water resources field, OWRR's role is clearly established after five years of operation.

DECEMBER 1, 1969

REPORT AND RECOMMENDATIONS OF THE SPECIAL PANEL[1/] CONVENED PURSUANT TO REGULATIONS OF THE SECRETARY OF THE INTERIOR (CFR Chapter IV, Section 506.5) TO ADVISE ON THE OPERATIONS OF THE OFFICE OF WATER RESOURCES RESEARCH

The Panel met on November 18 and 19, 1969 in Washington, D. C. to review the operations of the Office of Water Resources Research after having been furnished a draft of 1969 Annual Report and the published 1968 Annual Report. The Director of the OWRR, Dr. H. G. Hershey, and its Associate Director, Mr. E. D. Eaton, made themselves available throughout the Panel meetings, presented summaries of pertinent current information, provided additional documentation requested by the Panel and answered questions raised during the Panel's deliberations.

After consideration of the draft of the 1969 report, previous annual reports, recommendations of previous Panels and the specific purposes of the Water Resources Research Act of 1964, the Panel concluded in general that the 1969 Annual Report effectively portrays the current situation, that the broad purposes of the Act of 1964 are being accomplished in a number of significant ways, that the administration of the Act by the OWRR is to be commended and that there are a number of areas that deserve consideration for increased emphasis or new action.

WATER RESOURCES RESEARCH INSTITUTES (ALLOTMENT PROGRAM)

The general purpose of the allotment program is to provide financial support to each State for operation of an institute to conduct water research and to train scientists and engineers by student participation in approved research projects. The established institutes in the 50 States and in Puerto Rico were granted $100,000 each in 1969, a total of $5,100,000. Although matching non-Federal funds are not required, the States are contributing nearly $4,000,000 and have 460 research projects in progress with more than 1000 students participating.

By far the most effective instrument for analysis by the Panel of the activities of the institutes is the summarization in this annual report for the first time of highlight reports by the 51 institute directors. The Panel believes that this practice should be continued, refined, and utilized in many ways.

First, it can provide the OWRR, its advisory panel and the 3000 or more recipients and readers of the OWRR annual report with a practical means of understanding this aspect of the objectives of the Water Resources Research Act. Few readers of the annual report of OWRR can go deeply into all of the individual State institute reports or into even a few of them. Without a general awareness of what is happening in every institute, it is difficult to judge what can and should be done beyond the efforts of the institutes. Secondly, each institute can profit by the experience of the others. Ideas can be gleaned for better formulation and conduct of individual institute programs, for possible inter-institute or regional activities and for the most effective role of the institutes in accomplishing the total of the purposes of the Water Resources Research Act.

Finally, the institutes can, through knowledge of each others methods, policies, and results, become effective instruments in bringing the results of their own and others research into practical application through the decision-making processes pertinent to their respective areas and problems.

The Panel visualizes communication of research results and implications as an important role of the institutes as well as of OWRR itself. This does not mean

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[1/] The composition of the 9-member Panel is recorded on page xx.

that an institute should assume the role of an advocate for or an opponent of specific solutions to water problems. Rather it means that an institute can and should utilize all means available to it, such as advisory panels, seminars, newsletters, and other media for contact with the public, such that the effect is to provide the public and ultimately, the decision-makers, with authentic information rather than with uninformed opinion or even misleading information as a basis for decisions on water management.

The Panel, therefore, urges that the institutes utilize every means available to them to enhance public understanding of research findings and their implications as to the type of public and private action and decisions needed to make the results of research effective. This is being done in various ways in some centers and should be a continuing objective of all institutes, not only for its obvious benefits in improving decisions on specific current local problems but in providing improvement in administrative and legislative procedures for solving future water problems.

It is noted that many institutes are already able to report examples of the application of their work to the solution of specific problems. This is gratifying and should be used as a major element of justification in support of the fullest possible utilization of the institutes' activities. Specific examples of monetary savings improved decisions and other tangible evidence would be particularly useful in this respect.

Among the types of possible institute activities that are not frequently mentioned are regional activities, inter-disciplinary action, and use of advisory groups. The Panel considers these as important aspects of the role of the institutes and hopes that future reports of directors will show what has been and can be done along these lines.

In discussion with the OWRR staff, the Panel gained the clear impression that direct contact between OWRR staff and the institutes has not been extensive. The Panel believes that OWRR staffing should be augmented to meet the institutes needs and desires in this respect.

The results of the institutes activities to date have been remarkable considering the variety of problems, procedures and resources available to them. The Panel believes that the general practice of vesting the responsibility for heading, guiding, organizing and decision-making in the institute in outstanding men who also have other responsibilities in their universities is sound. However, consideration should be given to an "executive-secretary" and small permanent staff setup devoted exclusively to institute affairs whenever warranted by the scope of activities and other circumstances involved in the arrangement for the institute.

The Panel is well aware that the foregoing observations imply greater financial support for the institutes than is now available. The Panel urges such additional financial support and specifically endorses the proposed amendments to the Water Resources Research Act recently developed by the Universities Council on Water Resources and the National Association of State Universities and Land-Grant Colleges, the main effect of which would be to increase the authorization for annual allotment from \$100,000 to \$250,000. The Panel believes that this specific amendment as well as the accompanying amendments proposed by UCOWR should be adopted.

MATCHING GRANTS TO THE STATE WATER RESOURCES INSTITUTES

Under this program, the State institutes compete with each other for Federal funds which they are willing and able to provide to permit their sponsorship of specific research projects not otherwise fundable because of the projects and activities they have elected to support with their "allotment funds" as discussed above. Whereas the nature and scope of the allotment program results in concentration on local problems as was intended by the Water Resources Research Act and requires only general guidance by OWRR to avoid duplication and unnecessary effort, the matching grant program requires consideration of the national interest and major problems of regional or extraordinary local significance. The results have been that more than three-quarters of the available Federal funds for matching have been channeled to the currently designated major national problem areas.

The basic Act authorizes $5,000,000 annually for this purpose. In 1969, $3,000,000 were appropriated and applied to the most promising of $8,700,000 worth of matching grant requests.

The Panel considers that OWRR has obtained the best possible advice in appraising these requests and has administered this phase of the program effectively. It also considers that the full amount of $5,000,000 annually now authorized should be appropriated because the opportunity for an equal amount of non-Federal funds is not being fully utilized for worthwhile and urgent projects which fall within the categories of major national problems.

CONTRACTS AND GRANTS TO ORGANIZATIONS OTHER THAN INSTITUTES

Under this program, $8,000,000 was authorized and only $2,000,000 appropriated for use in 1969 to contract with or grant to any institution, public or private, for research considered desirable by OWRR and not otherwise provided for in the allotment or matching grant programs. In 1969, 320 usable proposals at an estimated cost of $38,000,000 were received. Of these, 31 were funded within the $2,000,000 available. There are now 62 projects being funded under the Title II program. Universities (other than Title I institutes) have 35, 20 are in private industry, 4 in non-profit research foundations and 3 with State and local governments. Practically all of the projects are within the categories designated as most important to improvement of water resource management.

This is the area which is most demanding in discrimination and judgment by OWRR itself. The Panel believes, however, that it is an area that offers the most flexibility in use of Federal funds for rounding out the total requirements for research on the most urgent water problems. The national interest rather than solution of local problems is and should be a major consideration in selecting projects in this category. Also the flexibility for utilizing special talents and inter-disciplinary combinations not available in the other programs is an important factor in support of the Title II procedure. This is the only area in which the OWRR staff can exercise initiative in formulating research projects that are needed to balance the fulfillment of the total objective and which are not forthcoming through the processes of the allotment and matching grant programs. Finally, this is the area where special talents not available to the institutes can be brought to bear on recognized problems.

The Panel considers that the OWRR administration of the Title II program deserves commendation. It believes that the OWRR analysis and review procedures for Title II proposals, which include advice from the most knowledgeable sources on the subjects concerned, result in the selection of the best projects and best executors of those projects. Proposals received far exceed the number fundable both in numbers of projects and costs. After careful rating of the urgency, relevancy, possible usefulness, competency of the researchers and many other factors, the OWRR has not yet been able to accept any proposal which has not been adjudged as number one or two on all of the several criteria applicable in the selection process. One of these criteria which the Panel considered important is that the project should not be approved if it is merely the solution of a problem that could be arranged for by direct arrangements with an engineering firm or similar agency available to the organization which has the problem. Another is the competency of the talent and resources available to the contractor. The Panel is well satisfied that these and other criteria are being well appraised through its staff and advisory procedures. The Panel is further convinced that this phase of the OWRR program deserves expansion and additional financing.

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OWRR ACTIVITIES IN GENERAL

The Panel's reaction to its review and discussion of specific current and proposed activities of the OWRR is generally favorable and commendatory. It has not attempted to review nor to analyze progress on all recommendations of previous panels but in general concurs with them and believes satisfactory progress is being made in their direction.

The Panel was advised that a brief summary of the OWRR annual report designed for wide distribution and general understanding of the activities under the Water Resources Research Act is in preparation. The Panel's reaction to this development was mixed and suggests future appraisal of the usefulness of the extra effort required for this innovation and comparison with the effectiveness of other efforts toward improved communication, public understanding and awareness and desirable involvement of all concerned with improvement of water management.

The growth and increasing utility of the Water Resources Science Information Center (WRSIC) has been noted. The Panel concurs with the previous conclusions of the importance of this activity and the current plans for its improvement.

AREAS OF EMPHASIS

In its review of the contributions of the Water Resources Research Act programs to the 10 major problem areas identified by the Committee on Water Resources Research of the Federal Council for Science and Technology, the Panel concludes that the activities under the Water Resources Research Act have contributed appropriately to their solution and in harmony with the contributions of these areas being afforded by the mission-oriented programs of Federal agencies and other research activities related to water. In addition, OWRR activities have produced additional emphasis on the significance of groundwater in the hydrologic cycle and in basic water knowledge generally.

Without reflecting adversely on the need for emphasis in the several generally recognized problem areas, the Panel was in agreement that the problem of improving water resources system planning and management processes, to which OWRR has directed great emphasis, continues to deserve special attention. This includes attention to the phase of research mentioned by the Senate Committee Report on OWRR's FY 1970 Appropriation Request (Sen. Rept. No. 91-420, 91st Cong., First Session, p. 22-23, Sept. 18, 1969) namely, the measurement of benefits resulting from water resource projects and the implications of such data on the formulation and evaluation of future projects. The Panel concurs completely in the need for this type of research and application of its results to future planning and decision-making. In this area and in the entire area of research needed for improvement of water planning, decision-making and management, the Panel is convinced that the case-study approach is a necessary first step and urges that all such possibilities be given high priority.

Again high on the list of major needs is research on water in relation to solution of urban problems. This is not to say that increased knowledge about water in rural and agricultural areas is not also important. In fact, the effects of water use in non-urban areas is often a major factor in urban water problems. Nevertheless, the Panel is convinced that research directed specifically to solution of urban problems requires special emphasis and increased support and is gratified to have been advised that the Secretary of the Interior has already directed OWRR to contribute to this objective.

CONCLUSIONS AND RECOMMENDATIONS

The 1969 Advisory Panel concludes that the operations of the OWRR to date are to be highly commended and that they have contributed significantly to the improvement of the management of the Nation's water resources.

The Panel recommends generally that OWRR follow up on the specific suggestions outlined in the Panel's report and specifically that OWRR take appropriate action towards the following ends:

1. Continuation and refinement of the summary reports by Institute Directors in the OWRR Annual Reports.

2. Expansion of the institutes' role in communication of research results and implications with a view to:

    (a) Application of research results to practice

    (b) Awareness by the public and decision-makers of the implications of research results.

3. Increased allotments to State Water Resources Research Institutes.

4. Increased funds for matching grants to the amount authorized and beyond if matching offers warrant.

5. Increased funds for Title II activities to the amount authorized and beyond if worthy proposals continue to exceed funding capability.

6. Augmentation and adequate funding of the OWRR staff to permit more direct contact with institutes and necessary activity on expended matching grant and Title II work.

7. Continuation of emphasis on research designed to improve water resources planning and management.

8. Added emphasis on research designed to contribute to solution of urban problems.

9. Increased use of case studies to provide information for improvement of planning and decision-making.

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Research under the PL88-379 program is concerned with many kinds of problems related to many types of water bodies such as estuarine areas and the Great Lakes, rivers, ponds, bogs, and springs.

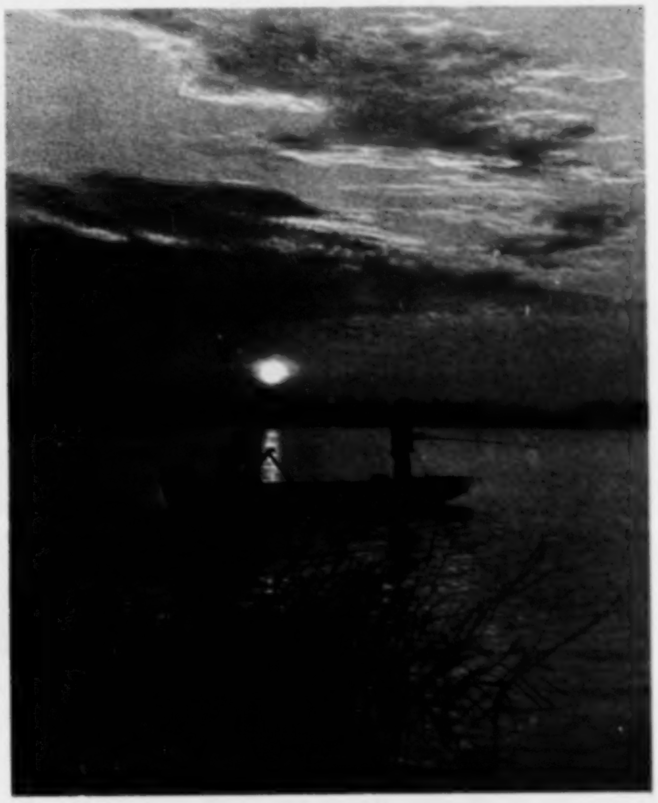
Continuous Plankton Recorder used in the research project A-011-Minn "A study of the open water distribution and abundance of net plankton as an index of eutrophication in Lake Superior"

Rainbow Springs, Florida

Photo, courtesy, Florida News Bureau

A small southern lake—Lake Tsala Apopka, Florida

Courtesy, Florida Development Commission



A fertile floodplain pool along the Kaskaskia River. Project B-025-Ill.
Photo, courtesy Illinois State Natural History Survey

Aerial photograph of 10-Acre bog at Jewell Hill, Stratham, N.H. The hydrology of this form of natural water retention is being studied by the Water Resources Research Center, University of New Hampshire.

Clear streams of the south Missouri limestone region are becoming a major recreation area for the mid-continent area. Research is showing how to keep streams clear and pure so fishing or "just floating" in a "jon" boat can be an enjoyable experience for future generations. Photo by Walker-Missouri Tourism

PART I

RESEARCH RESULTS AND THEIR APPLICATION

THE INCREASED NUMBER OF PROJECTS COMPLETED IN 1969 PRODUCED A LARGE VOLUME OF RESULTS HAVING FAR RANGING APPLICATION TO THE SOLUTION OF WATER RESOURCES PROBLEMS AT LOCAL, STATE, REGIONAL AND NATIONAL LEVELS. SELECTED EXAMPLES OF RESULTS ARE PRESENTED AS THEY APPLY TO TWELVE MAJOR WATER PROBLEM AREAS. THE EXPANDED SCOPE OF ACTIVITIES OF THE WATER RESOURCES RESEARCH CENTERS AND INSTITUTES ESTABLISHED UNDER THE ACT INDICATES THE INCREASINGLY IMPORTANT ROLE THEY ARE PLAYING IN THE RESOLUTION OF WATER RESOURCES PROBLEMS. THIS HAS RESULTED IN AN EXPANDING RESEARCH PROGRAM INVOLVING AN INCREASING NUMBER OF DISCIPLINES. TO DATE, INCLUDING COMPLETED AND ON-GOING STUDIES, OWRR HAS HELPED TO SUPPORT 1162 ALLOTMENT, 444 MATCHING GRANT AND 97 TITLE II PROJECTS. TITLE II PROJECTS HAVE BEEN CONTRACTED WITH 37 UNIVERSITIES AND 28 RESEARCH AGENCIES INCLUDING PRIVATE ORGANIZATIONS AND STATE AND LOCAL GOVERNMENT AGENCIES. THE ALLOTMENT AND MATCHING GRANT PROJECTS ARE BEING CONDUCTED BY 119 UNIVERSITIES.

Introduction

To exemplify how research contributes to problem-solving, recent results of OWRR-supported research are discussed as they apply to helping to resolve problem areas.

The first ten problem areas were taken from a May 5, 1969, working paper of the Committee on Water Resources Research, Federal Council for Science and Technology. Descriptions of the areas are condensed versions of the report which will be published by COWRR in final form at a later date. Figure 1 shows allocation of water research funds distributed by water resource problem areas for Fiscal Year 1970. Figure 2 shows allocation of water research funds distributed by OWRR by FCST category for Fiscal years 1967, 68, 69 and 70; and, Appendices K and L list research projects by State, Title, FCST category, principal investigator and fiscal years in which funded.

Research results and their application include examples of projects from the three OWRR research sponsored programs as follows: Allotment (prefix A); Matching Grant (prefix B); and Title II (prefix C). The twelve problem areas are:

1. Improving Water Resources System Planning and Management Processes
2. Control of Heated Water Discharges
3. Control of Sediment
4. Water Quality
5. Meeting Increased Water Supply Requirements
6. Mitigation of Water-Caused Damages
7. Conserving Ecologic Values in Water Resources Planning
8. Metropolitan Area Water Systems
9. Conservation of the Estuarial Water Resource
10. Dissemination and Application of Knowledge
11. Other Problems Related to the Hydrologic Cycle

12. Research on Other Problems Including Engineering Structures and Data Collection

Examples of results are from both completed and on-going research. Since some results are tentative and have not been published, readers are requested to consult with principal investigators for permission to cite findings. Investigators may be contacted through respective State Water Resources Research Institute or Center Directors as listed in Appendix S.

Only a few representative projects under each problem area are listed. For more detailed information on research activity by specific Institute or Center, refer to Directors' Statements, Part IV of this report.

Water problems being studied are many and varied.

The April 18, 1969 flood on Peachtree Creek in Northwest Atlanta vividly illustrates how lack of planning and management in urban watersheds has resulted in hazardous flood plain occupancy. This house is in an area being studied by an interdisciplinary research team at Georgia Institute of Technology, P.L. 88-379 under a Title II Grant

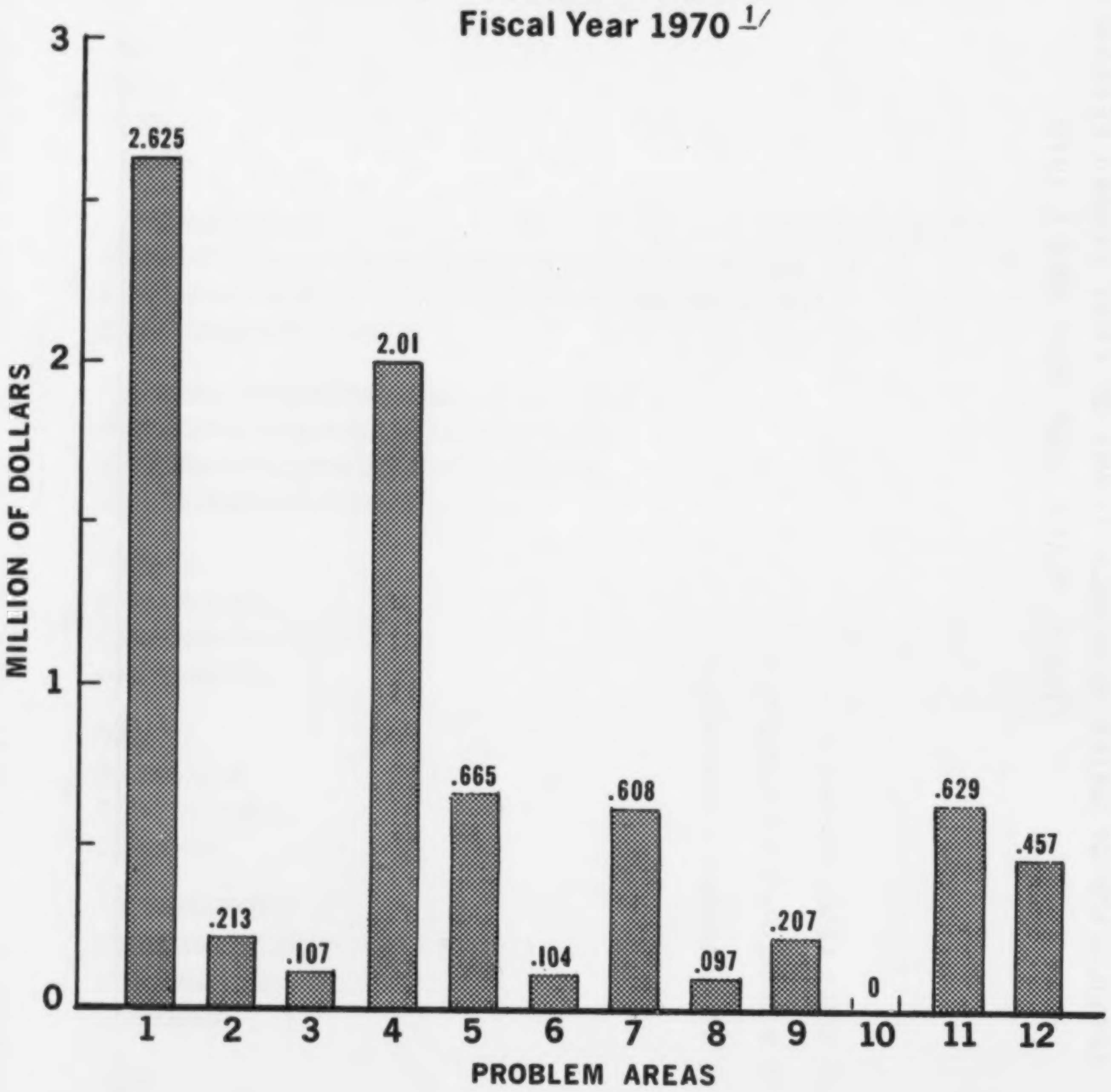
Floods are a problem in urban, suburban and rural areas.

Flooding in the Minnesota river valley in 1969

Photo, courtesy Minnesota Water Resources Research Center

FIGURE 1

APPLICATION OF WATER RESEARCH FUNDS BY PROBLEM AREAS Fiscal Year 1970 1/



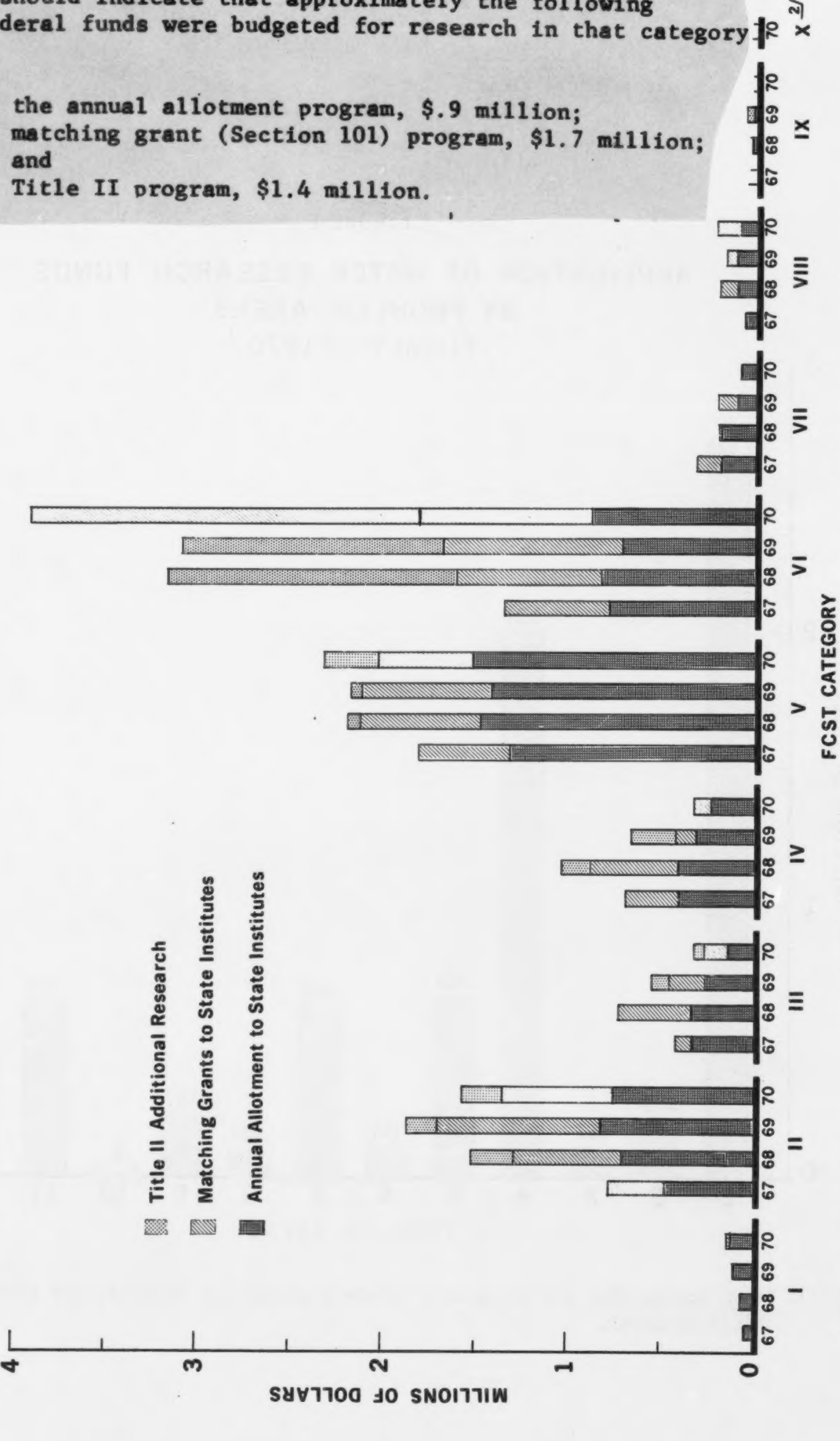
1/ Funds appropriated and allocated for research project cost, $9,827,519,F Y 1970 (As of 10/10/69)

Page 4, Figure 2. The bar graph for Fiscal Year 1970, above Category VI, should indicate that approximately the following amounts of Federal funds were budgeted for research in that category in:

- (a) the annual allotment program, \$.9 million;
- (b) matching grant (Section 101) program, \$1.7 million; and
- (c) Title II program, \$1.4 million.

FIGURE 2

APPLICATION OF WATER RESEARCH FUNDS BY FCST-COWRR RESEARCH CATEGORIES FISCAL YEARS 1967, 1968, 1969 & 1970[1]



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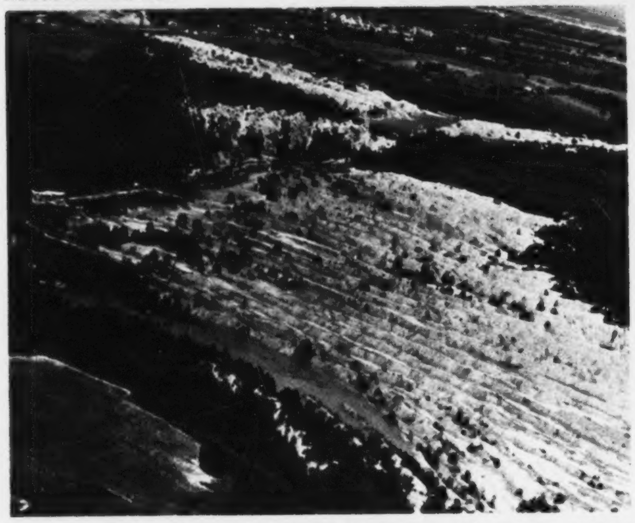
[1] FUNDS APPROPRIATED AND ALLOCATED FOR RESEARCH PROJECT COSTS; FY 1967-\$5,557,000; FY 1968-\$9,061,000; FY 1969-\$9,018,356; FY 1970-\$8,827,519; (as of 10/10/69)

[2] NEW FCST CATEGORY FOR FY 1970

Photo, courtesy Missouri Water Resources
Research Center



Drainage from strip mines can be an important source of water pollution. Vegetation is slow to return to this area in Missouri where coal has been removed.

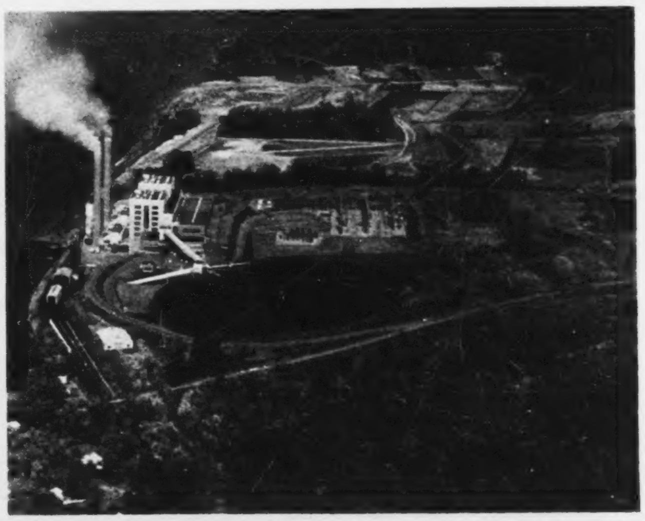
Problems may arise from the juxtaposition seen here of feedlot-lake-recreation area. Photo, courtesy South Dakota Water Resources Institute

Major new deposits of minerals are being developed in southeast Missouri. Mining companies are cooperating with Projects A-021-MO and B-021-MO to insure that streams of the area will continue to provide water of high quality.

Problems of Water Quality

Several Georgia projects are concerned with urban water resources management. One new project (B-045-GA, York), as well as a Title II project (C-1323) is specifically concerned with flood management in an Atlanta drainage area, shown here during the April 1969 flood.

New York State Electric and Gas
now operates the coal-fueled generator
plant Milliken station on Cayuga Lake.
The Company's plans to build a nuclear generating plant adjacent to Milliken have resulted in two of the most complete studies ever made of a stratified lake.



Photo, courtesy New York State College of Agriculture at Cornell University

Water from a steam generating plant at Thomas Hill Reservoir has made winter fishing a popular sport in this area of Missouri. A fine limit-catch of large mouth bass and one white crappie, laid on the snow to cool. Temperature 20°F, January, 1968. Photo by Arthur Witt, Jr.

Sociologists, Dennis C. Geertsen (left) and Dr. Wade H. Andrews (right) of Utah State University examine a collection of headlines dealing with social problems associated with water use and development.

Many problems are socio-economic in nature and include development of methods for valuing fish and wildlife and recreation.

Investigator interviews boaters at marina launch in North Carolina study of the recreational capacity of reservoirs and lakes (B-013-NC)

A North Carolina study (B-010-NC) deals with economic effects of land use on the yield of water from municipal watersheds.

Improving Water Resources System Planning and Management Processes

Statement of the Problem

Water resources planning requires identification and acceptance of relevant social goals established through democratic processes. These goals represent a balance among factors of national economic efficiency, regional development, environmental quality, the public well being, and preservation of flexibility to meet changing requirements.

This problem area involves development of methods for evaluating probable effects of water resources plans on these objectives. Research will involve among other considerations: determining the relation of water resources planning to other regional and functional plans; developing effective methods for analyzing probable consequences of proposed water resources programs; and evaluating and developing institutions for planning and policy decisions required to meet social goals.

Research

Techniques of Planning

New Mexico has a unique interdisciplinary-interuniversity project (B-011-NMEX) involving principal investigators located in seven academic departments at three universities. The study is entitled "A Comprehensive Water Resources Analysis of a Typical Overdrawn Basin in an Irrigated Semiarid Area - Pecos River Basin, New Mexico." Preliminary subproject research for each discipline, geology-hydrology, civil engineering, agricultural economics, agnonomy, economics, and law is being completed and reports written. Through coordinating meetings and by close working relationships between groups, the gross systems analysis, legal aspects, and preliminary reports, by discipline, are being coordinated into an overall final report which will be completed by April of 1970.

The final report is expected to be highly useful to decision makers at local and State levels in water resources management of Pecos Basin. Also, results are expected to be applicable to other overdrawn basins in semiarid areas of the southwest.

The overall objective of a research study in Texas (B-024-TEX) has been to develop multistage optimization methods which would permit incorporation of water quality management into the problem of planning for optimum beneficial use of water resources within a planning region. Specific tasks conducted in this investigation included: (1) development of needed optimization techniques, (2) formulation of analytical models, (3) development of solution algorithms, and (4) application of algorithms to a field problem (Trinity River Basin).

In this study, multistage optimization methods have been developed which permit efficient computational analysis. However, lack of adequate basic data on water resources seriously hampers use of the model. Also, to successfully solve modern-day water resource systems it is necessary to simplify analytical detail of the model or decompose the problem into more manageable parts. It is believed this approach will become more useful as quality of physical data improves and as water resource planning problems become more complex.

A research project (C-1318) entitled "Stochastic Basis for Comprehensive River Basin Planning" is being conducted at Union College, New York. Three digital computer programs were written one of which is a mathematical representation of a single river branch with a series of population centers and associated sewage treatment plants along its banks. The method of gradients was used to obtain an optimum set of treatment plant efficiencies that would minimize total cost of water resources for the entire river.

The ultimate objective is to apply stochastic methods to systems analysis of river basins. Potential of the program is being further explored in project (C-1702) which will utilize physical parameters and economic efficiency functions in applying optimization theory to the integrated model.

Under project C-1034 a variety of stochastic programming models for determining alternative operating policies for multipurpose reservoirs have been structured, tested and, in cooperation with the New York State Department of Conservation, applied to regulation of the Finger Lakes in New York State. These models have used both linear and dynamic programming techniques for their solution. Operating policies derived from these models are defined for reservoirs that serve a variety of complimentary and competing uses, requiring multiple objectives.

Perhaps the most significant contribution has been development of stochastic methods for defining both design and policy of a water resource system having a variable streamflow. Models that consider design as well as operating varables of river basin systems as unknown have been successfully applied to the Delaware River Basin in an effort to select preferred designs and policies for further analysis by simulation. Simulation studies indicate stochastic design and policy models are more effective for preliminary screening of alternatives than deterministic models.

Stochastic design and policy models have also been applied to defining alternative low-flow augmentation policies. This application will be published in a forthcoming book by the Harvard Water Program.

A long range study (C-1377) on systems simulation for management of a total water resource is being conducted by the Texas Water Development Board. This research represents a first step towards development of a computer-oriented planning system for use in planning of large, multi-basin systems of reservoirs and connecting river reaches and pump-canals such as the proposed Texas Water System.

Planning problems associated with the Trans-Texas Division of the proposed Texas Water System were used to guide development of the programs and procedures. Follow-on applications of these programs, sensitivity analysis, and program improvements will be carried out in project C-1975.

Experts in stochastic hydrology from Illinois concerned with intangible factors of overall water resources planning propose, in project B-030-ILL, a basic model of a hydroeconomic system for optimization. The proposed model, utilizing conjunctively surface water and ground water, may be applied to practical irrigation, flood control, and pollution abatement problems.

A multiphase study in Indiana involving three projects (A-012, A-013, and A-014-IND) applies systems analysis techniques to water resources planning and management practices in the Wabash River Basin. The recently initiated three-year study is expected to lead to improved utilization of the basin's waters.

North Dakota research project (B-007-NDAK) is designed to evaluate methods of irrigation for the purpose of identifying design or designs which maximize returns to resources in a sub-humid climate.

Computational models which simulate operation of specific types of sprinkler irrigation systems are applied to long term climatic records of a test area. These models will compute probability distributions of parameters (i.e., number of irrigations, days of system operation, acre-inches of water pumped, crop yield potential, etc.) which may be used to evaluate physical and economic potential associated with a specific system type, capacity, and imposed management regime. These parameters are applied to specific combinations of physical parameters (soils, crops, and irrigated unit size) and relevant cost and return functions can be applied.

Results are expected to provide the planner with basic information needed to estimate physical adequacy of a given design as well as associated economic evaluation.

The New York State Conservation Department, Division of Water Resources, is conducting a study (C-1126) of use of systems analysis in development of water resources management plans for New York State. The research, being carried out in connection with a State planning study in the Oswego River Basin, has developed two simulation models. One deals with flow of water during flood periods, computes lake levels, rates of flow in major streams, and stages of major streams on short time intervals. Damages occurring under various storm conditions and management procedures can be computed. The second model routes, or budgets, monthly flows and operates the system of lakes to meet needs at key points for uses such as navigation, water supply waste assimilation, irrigation, recreation, fish and wildlife enhancement, and power. Problems with basic hydrologic data have been encountered with both models but, steps are being taken to correct the situation.

An optimization model utilizing dynamic programming has also been developed. Hopefully, it will point out the most promising means of operating the system from the infinite number of possibilities. These will then be tested through simulation and it is expected the models will provide the analytical tools for studying issues of basin-wide impact.

In another New York study (B-017-NY) the object is to evaluate alternative techniques for involvement of the public in water resources planning and development. It will accomplish this through measurement of attitudes, preferences and awareness of community leaders and agency personnel before and after an experimental program of public involvement in a small basin currently undergoing an intensive planning effort. It is hoped this study will result in new approaches by planners to water resources development and to greater public understanding and involvement in the planning process.

Land development in vicinity of large multipurpose reservoirs poses many problems in water resource management. Demand for reservoir shoreline usage is increasing rapidly and conflicts between uses of the reservoir and shoreline development are becoming acute. North Carolina project B-012-NC involves development of a forecast model for testing of alternative policy mixes for their effectiveness in promoting desirable land development patterns around multipurpose reservoirs. A concurrent study (B-010-NC) of the Durham Municipal Watershed is investigating effects of various types of land use on water yield, quality and cost.

In Missouri, 125 public water districts are either in operation or in process of being developed. Information on these water supply districts supported by the Farmers Home Administration has been secured (A-018-MO). Among aspects studied were attitudes of the people being served and problems of operations. Districts are bringing ample amounts of high quality water to farmers and villages that previously lacked water meeting public health standards. It is believed this new utility is halting or reducing population movement from rural areas to cities in localities being served.

Evaluation Process

In a case study of Clinton County, Pennsylvania (A-009-PA), the principal investigators have provided an imaginative demonstration of the effectiveness of input-output analysis for decision-making in water resource planning and management. The basic approach was development of a combined money flow-water flow input-output model for the county based on intensive local sampling of economic activity in which economic activity and water usage (both quantity and quality) are related. One of several interesting applications of this model was the analysis of a series of "real-life" alternatives for dealing with the problem of water quality requirements for a large paper mill in the county, such as:

1. Accepting loss of the industry from the area because of poor water quality.
2. Providing high quality treated water to the company from the local water utility, passing full costs on to the mill.
3. Sharing above costs with the mill.
4. Various tax measures applicable either to the mill or public-at-large.

The model clearly indicated direct and indirect economic consequences of the above alternatives, providing decision makers with highly significant facts for making their judgments.

Minnesota project B-031-MINN is designed to study Participatory Ecology groups in Minneapolis-St. Paul, Miami, and two other metropolitan areas in the USA. Major research objectives are to: (1a) Identify and analyze structure, function and process in Participatory Ecology groups in each of the above areas; (1b) Determine linkages with other Participatory Ecology groups across the country, and also with other groups engaged in social action human rights; (1c) Determine processes in movement formation, or impending factors. (2) Determine extent to which ideology and activities of Participatory Ecology constitutes an attempt to redefine man's relationship with the water resources environment. (3) Assess the adaptive significance of Participatory Ecology in promoting ecological thinking and improving quality of the water resources environment, particularly of urban areas, by such means as: (a) influencing power elite; (b) involving people at grass roots; and, (c) experimenting through trial and error in water resources environmental problem solving. (4) Expanding knowledge about the social movement structure function, process, capability and limitation. The three-year study should provide results useful for evaluating the role of group action in improvement and development of water resources.

In North Dakota the economic impact of construction of the Garrison Diversion Irrigation project was studied (B-002-NDAK). The initial phase of the project will permit irrigation of 250,000 acres. Ultimately, 1,000,000 acres are scheduled for irrigation when the project is completed.

The study area selected was seven counties in southwestern North Dakota. With agriculture as the major basic industry an input-output study was made to project economic impacts of changes in the economy resulting from the Garrison Project. Interdependence coefficients based on regression coefficients were applied to increased agricultural incomes expected to result from the first 250,000 acres to be developed. This computation indicated that the expected $12,979,000 increase in agricultural income would result in an additional income of $28,184,000 (multiplier effect) in the local economy. The analysis also indicated expected distribution of this income among 30 sectors of the local economy.

Another study in the Northeastern part of North Dakota (B-002-NDAK) was designed to describe the economy of a ten-county area prior to start of construction of irrigation and water-based recreation development expected to result from Garrison Diversion project. Input-output analysis will continue on a long-term basis to permit measurements of the economic impact of water-based development in the area as it occurs. Results to date are being used by the Cooperative Extension Service in their resource development program in the area.

A study (B-007-COLO) on economics of ground water development in the high plains of Colorado was completed using recursive linear programming methods for analysis. Life expectation of ground water aquifers was estimated for three different areas. These estimates ranged from approximately 40-150 years depending

Quantification of statistical demand functions for five outdoor recreation activities has been the objective of B-014-NY. Resulting functions have been used for projecting future demand for these activities, their economic value, and the effect of systematic pricing mechanisms on demand in New York State. A research bulletin reporting results of this phase of the project is being published. Hopefully, results can be integrated with planning programs for the Finger Lakes Region of New York.

In Ohio, project A-009-OHIO explores public investment criteria for water oriented recreation in the Lake Erie Basin. Two parts of the project, the investment study and demand study, are being combined and conclusions drawn on the significance of various funding measures, including pollution taxes, user charges, and other revenue sources.

Water Demand

Results of the joint Arkansas-Oklahoma projects B-001-ARK and B-006-OKLA dealing with water resources planning of interstate waters have been used by the Arkansas-Oklahoma Compact Committee in recommending apportionment of joint water resources of these States. Through proposed computer studies based on recorded flows, simulated storage and accompanying losses, the project is expected to provide a means of predicting flows and water quality for use in water planning and management.

In project B-002-NJ a comprehensive analysis of man-made organic pollution of three important New Jersey river basins was completed and correlated with population and industrial growth rates. Results indicate unrecorded pollution sources such as storm drain runoff, agricultural activities, septic tanks, and spills greatly exceed pollution loading emanating from recorded effluents. Based on basin-wide analysis of BOD loading for the Passaic River, it was possible to compute the number of aerators required for an FWPCA-sponsored demonstration project that Rutgers performed. This demonstration project utilizing in-stream mechanical aerators produced promising results that could conceivably lead to utilizing mechanical aerators as an adjunct or substitute for conventional sewage treatment.

During the past year, Hittman Associates of Columbia, Maryland, made significant advances in building on their "MAIN I" system of computerized models for estimating municipal water requirements. In project (C-1396), a computerized predictive system was developed which calculates and projects municipal water requirements, based on specific demographic, economic, and climatological data. This system is being utilized by Gulf South Research Institute as part of a comprehensive water and related land resource plan being prepared for the Department of Public Works of the State of Louisiana. It is expected the system will also be used in the Mississippi River Commission's Water Needs Study for Louisiana.

In an allied effort (C-1397), Hittman Associates developed a system of generalized models for computerized evaluation of a wide spectrum of water conservation practices.

The purpose of Georgia project B-011-GA was to determine price and income elasticities for water consumption in the humid Southeastern United States. Householders in 14 municipal water systems were interviewed for socio-economic characteristics and water consumption was correlated with these characteristics. Physical factors, such as lawn area, did not significantly affect household consumption of water. However, there were definite differences in consumption of water due to variations in prices of water and incomes or income surrogates such as value of the residence. Price elasticities were generally about -0.68 and income elasticities were generally about +0.80. Industrial consumption in poultry processing plants, textile finishing and pulp manufacturing varied considerably among plants in each industry according to gross use and use per unit of product.

Pages 11, 12 and 13. These pages are misnumbered and out of order. In reading, please turn from the bottom of page 10 to page 13, thence to pages 11 and 12 for proper continuity. Items relating to examples of research discussed on these pages appear in the Index (page 328) according to the pagination in the report.

However, these variations appeared more closely related to such things as age of plant and management practices and not to price of water nor to value of marginal product produced by that water.

Water Law and Institutions

A study (A-015-MINN) on hydrologic and other aspects of water laws and major court decisions in Minnesota had, as part of its objective, determination of the extent to which statutory laws and court decisions reflect existing scientific knowledge of the hydrologist. Other aspects of water laws with which the study was concerned include: areas of inconsistent regulation; extent to which water policy has been defined and developed by existing water laws; extent to which priorities of use have been established by existing water laws; effectiveness of existing water laws in dealing with specific problems; and, water law obstacles to effective water resource development and management.

The study indicates direction in which State water law is moving, and offers suggestions concerning areas where legislative efforts might be placed with respect to hydrologic and other important aspects of water law. This compilation is an excellent water law source reference.

In Alabama, project B-012-ALA has dealt with legal aspects of water resources use in relation to economic development. This State, with an abundant supply of water, has had few serious water problems resulting in litigation during the past few years. However, demand for water is increasing with industrial and urban growth and eventually conflicting demands will be settled in the courts. In anticipation of this, the study explored legal alternatives for control of water use, such as zoning and permit systems, designed to prevent serious conflicts.

Two Kentucky projects (A-020 and A-022-KY) are concerned with problems imposed on people because of water developments which result in some form of cultural change such as having to move. In the Salt River Basin near Louisville, ecologic impacts of a reservoir scheduled for construction will be studied, including human ecology as well as effects on flora and fauna. Hopefully, the study will provide a better understanding of human problems in such undertakings to the end that greater facilities for adjustment might be afforded people in similar future efforts. Through a combination of studies--some completed and others recently initiated--the biological, sociological, anthropological, and economic values as affected by the reservoir development will be appraised.

Engineering Science, Inc. is completing a study (C-1496) on systematic evaluation of management effectiveness of the Regional Water Quality Control Board System of California. A computer-operated simulation model of the decision-making process of the Regional Boards has been developed and is being used to examine factors involved in the water quality control function. Results of simulation runs will be used to gain insight into characteristics and structural elements of decision-making in water quality management, with expected application to policy-making in this field.

As a follow-on project Engineering Science will study decision processes in water quality management (C-1736). This study will evaluate, using dynamic simulation techniques, decision-making processes at both agency and group or individual levels in the multi-agency system of water quality management. A decision situation simulation package will be developed which can be used by water resources management and policy-making groups to evaluate their own decision-making processes.

"Institutional Factors Influencing Water Development in Texas" is the title of project B-025-TEX. Two kinds of land-water developments have been studied to discover and analyze institutional factors which have been and will be important. One is development of land and surface water resources of the lower Rio Grande for irrigation of crops. This is an area of intensive development and use, but on (a) rate of well development, and (b) annual adjustment in enterprises. Each area was programmed first with an assumption of restricted well development and then increasing development. If well development is restricted on current levels, economic life of the aquifer will be as long as 150 years in some cases. If current well development is doubled every five years, irrigated agriculture will become unprofitable in approximately 40 years.

This project is highly relevant to current ground water problems in Colorado. The Colorado Ground Water Commission has been furnished an economic analysis for use in policy and planning showing alternatives facing High Plains water users in a ground water mining situation.

Project (B-005-FLA) is concerned with development of an optimum water allocation scheme for the extremely complex water system of the Kissimmee-Okeechobee-Everglades region of central and southern Florida. The Central and Southern Florida Flood Control District was created in 1948 to provide relief from flooding. A complex system of canals, levees, pumping stations, spillways, navigation locks and retention basins has been developed, the operation of which is prescribed by rule curves developed with flood control as their primary purpose. Since 1948, when the District was created, critical water shortages in the Everglades and objectives other than flood control have become increasingly important. Among these are water supply, public recreation, fish and wildlife conservation, protection of ground water from salt-water intrusion, irrigation, agricultural drainage and improvement of navigation.

This study will help in determining water management policies and operating procedures for optimizing allocation among these needs.

A Utah study (B-004-UTAH) on economic effects of water allocation among alternative industrial (non-agricultural) uses estimated increased demand for water in the State between 1963 and 1975 to be 1,455,000 acre feet. Crops are expected to require 1,203,000 acre feet and non-agricultural sectors 252,000 acre feet.

As was suspected, the marginal income value of water to the State was found to be lowest for crops. The marginal income value was highest for some of the services categories. The study was regarded as providing a basis for forming a list of priorities on the relative marginal value of alternative uses of water, and on the relative needs and scarcity of water.

Water Resources Engineers firm of California has made encouraging progress in developing an objective methodology (C-1477) for determining the value of a wild river and providing the basis for decision-making on whether such a river should be allowed to remain "wild," developed to a small extent, or developed fully to produce traditional economic goods and services.

Two forward-looking methods are being worked out. The first expresses economic growth patterns of river basins in mathematical terms so that relationships between benefits to be derived and costs to be incurred under various levels of development can be made explicit. All terms, both benefits and costs, are being treated as monetary values. The second method is based on the requirement that all values, both monetary and non-monetary in nature, shall be reduced to a common unit of expression. This means that each element, e.g., dollars, picnics, and redwoods will be treated according to a common numerical procedure. Measurable dollar-benefits will be increased by a multiplier that reflects nonmeasurable benefits that are either illusive, secondary dollar-benefits or those having inestimable esthetic value.

Expected results, not heretofore achieved, should enable quantifications of esthetic values and sound standardization of the evaluation procedure.

with considerable problems of efficiency of use of land and water. Institutional arrangements have contributed to these problems, for example: (1) uncertainty in water rights has caused under-investment in facilities, (2) proliferation of special districts has prevented attainment of optimum size of distributional units, and (3) inappropriate water pricing policies contributed to inefficiency of use of water. Effects of changes in these and other institutional arrangements on efficiency of water use has been and is being studied.

The second development studied was land and Water Development of the High Plains for agriculture, industrial and municipal uses. Work has involved consideration of institutional factors affecting both ground water and transfers and use of imported water. Significant institutional factors were studied in terms of their possible positive and negative effects as the plan is implemented.

Project A-024-GA will examine effects of municipal water service policies on economic growth of suburban areas and will involve investigations in 20 Georgia cities with populations between 5,000 and 100,000. Effects of various water extension policies on recent industrial growth will be determined. Findings will be used to establish guidelines on water management policies designed to attract new industries.

ProjectA-012-NMEX is a study of the history of water utilization in New Mexico and the Southwest--with particular reference to the impact of legal and institutional controls on water management. Investigations are being made of the evolution of water law in New Mexico and the influence of Indian, Spanish and Mexican law and custom as it has persisted in the State. Development of New Mexico water law is being compared to other Western States. State impact of legal interpretations and effects of certain federal legislation on water law is being analyzed. Other factors being studied are: Impact of interstate and international river compacts; extension of state control over groundwater; and broadening of the pioneer concept of water use for domestic, agricultural and mining purposes to a much more comprehensive base.

A Title II multiphase grant (C-1228) with the University of Wisconsin has been organized into a critical path framework directed to technical and institutional aspects of water quality management. Results expected will permit comparison of total cost of a minimum cost system, with total cost if uniform reductions in waste discharges are required of all waste producers. Also demonstrated will be limitations of existing institutional arrangements for realization of potential economies.

In a Connecticut project (A-012-CONN) an economic evaluation has been made of the State's water law system. Considerable attention has been directed to interrelationships among laws pertaining to water rights, public water supply and pollution control.

Three economic concepts have been used. First, use of water resources depends largely on costs and benefits resulting from particular uses, and, as far as possible, rights and regulations should give consideration to all potential water users. Second, rights and regulations should be sufficiently stable to encourage investment and yet provide for reallocation of use in the course of time. Third, there should be economic incentives to encourage reducing consumption and waste and improving waste treatment processes.

Major conclusions of the study are: (1) uncertainties and inflexibilities often associated with riparian rights have not impeded development of withdrawal uses; (2) a permit system should be established for major ground water withdrawals; (3) riparian rights have not been effective in protecting recreational uses; (4) there is need for legislation to protect non-commercial uses from diversions for public water supply and detention for hydroelectric production; and, (5) effluent charges would be valuable in encouraging research on pollution control, but should not be relied upon to limit waste.

Primary emphasis of project A-013-NEB will be on legal alternatives for achieving efficient conjunctive use of ground and surface waters in Nebraska. An analysis will be made in Nebraska and other states, of legal-institutional-administrative structures through which water is transferred between competing users and uses. The following will be studied: (a) problems resulting from the present "dual system" of appropriative and riparian rights; (b) rights of overlying landowners to percolating waters that are tributary to a watercourse versus vested rights in the stream itself, whether appropriative or riparian; (c) what other States have done to reduce interferences between well owners and prior appropriators of surface watercourses; (d) problems of providing water supplies to towns and cities and to industries outside territorial limits of municipalities; and, (e) local districts in relationship to storage, groundwater management, and integrated use of ground and surface waters.

Control of Heated Water Discharges

Statement of the Problem

Temperature is one of the most important environmental factors controlling life on our planet. Through evolutionary processes, organisms have become adapted to living within various ranges of temperatures. Both the optimum temperature and range of temperature tolerance differ among species of organisms and constitute dominant environmental parameters affecting community structure and interspecies competition.

Various side effects from man's advancing technology and rapidly increasing population are producing significant changes in temperature in many natural habitats. Increased rates of energy production required by the Nation will be matched by comparable production of waste heat. Research is needed on: determining tolerance characteristics of healthy communities of aquatic forms in respect to temperature change; improving technology of heat dissipation and production processes of industries characterized by high heat loading of the environment; development of methodologies for site selection of plants to minimize detrimental effects of heat loading on the environment; and, evaluation of beneficial uses of rejected heat.

Research

A Missouri study (A-020-MO) is being conducted on a 4500-acre reservoir where heat from a 475 megawatt plant is returned to one arm of the lake. Results indicate heated water may have a beneficial effect on growth of fishes if it does not exceed their tolerance to high temperatures; it may provide a temperature regime which will allow introduction and survival of desirable forage fish such as the threadfin shad which typically has a more southerly distribution; and it keeps an arm of the lake ice-free during winter when the rest of the lake is frozen, and thus opens up a winter fishery for local sportsmen. Studies conducted in cooperation with the Missouri Department of Conservation, however, suggest that take of largemouth black bass concentrated in the warm water arm of the lake may be so high that this fish could be over exploited.

Much is to be learned regarding effects of heated water on aquatic biota. In an Arkansas project (A-007-ARK) mosquito fish (*Gambusia affinis*) were permitted to select temperatures in a tank where water temperatures were regulated so as to range from hot to cool in a series of connected compartments. Final distribution of the fish varied with sex and developmental stage. Males selected lower temperatures than did adult females and young fish occurred mostly at temperatures higher than those selected by adults. Such information may be of value in assessing impacts of heated water discharges on fish or aid in improving management of receiving waters.

Most studies aimed at evaluating the effect of heated water discharges have been devoted to effects on fishes and shellfishes. Virginia project B-017-VA, commenced July 1, 1969, is concerned with effects on microbiota protozoa and algae. These organisms are at the base of the food chain and their reduction or elimination will be reflected on larger, economically valuable organisms. Results should be useful in establishing water temperature criteria.

In Maryland, thermal pollution was one of the major areas of research. Projects A-002-MD and C-1401 provided very significant results in documenting harmful effects of thermal pollution on shellfish and finfish as well as on biota in their food-chain. One part of project A-007-MD was closely allied in researching means for discharging hot water jets into an ambient body of water with a minimum of thermal pollution.

Construction of a large power plant on the Mississippi River near Monticello, **Minnesota**, is scheduled for completion in February 1970. Heated water will be discharged from the plant during operation, causing changes in the environment.

Research at St. Cloud State College (B-032-MINN) is designed to determine existing ecological conditions in the river before operation of the plant and to monitor environmental changes due to thermal discharge from the generator. The 3-year study is expected to provide useful information as to the extent such changes are serious or damaging.

If problems of thermal pollution are to be solved, the mechanism of heat transfer from water reservoirs must be understood. Virginia project B-002-VA commenced July 1, 1969, will make analytical and experimental studies to determine various relationships of heat transfer from a liquid water surface. Results should be useful, not only in predicting effects, but in designing facilities to minimize problems from thermal pollution.

Some electrical generating plants on the Tennessee River system have experienced difficulty in having an assured supply of influent cooling water. It has been found possible, under certain reservoir operating conditions, for an electric generating plant to utilize its own heated discharge as cooling water. The Tennessee Center with cooperation of TVA personnel is conducting research (B-005-TENN) of considerable potential value in the siting of generating plants in relation to reservoir operation. The study is attempting to determine, in a laboratory flume, interaction between an open channel water body and the transient waves generated by time-varying discharges at the upstream and downstream ends of the reservoir. Results should be useful in determining improved reservoir operation for numerous purposes, including operation of existing electrical generating plants and better site location for future plants.

Work is under way in Oregon (B-009-OREG) to utilize heated water from nuclear power plants for beneficial uses in stimulating plant growth and extending the growing season in cold climates. The investigation is at present concerned with determining influence of soil temperature and heated water on rates of photosynthesis, transpiration and respiration under controlled laboratory conditions. This project is in response to growing public concern about thermal pollution in the Nation's streams. Coupled with this is a growing requirement for more irrigation water. If this project can demonstrate that warm water from a reactor will benefit certain crops, a two-fold problem will be somewhat alleviated.

A Rhode Island study (B-022-RI) is concerned with the design of a new community to recover waste heat from a proposed nuclear power plant rather than discharging it into adjacent coastal waters. This study will investigate residential, commercial, industrial and public benefits of such a plan, with consideration of effects on water ecology if the development of a power reactor is fully integrated with and made a focal point of a new community.

Water resources research requires both field and laboratory studies and a wide variety of techniques and equipment.

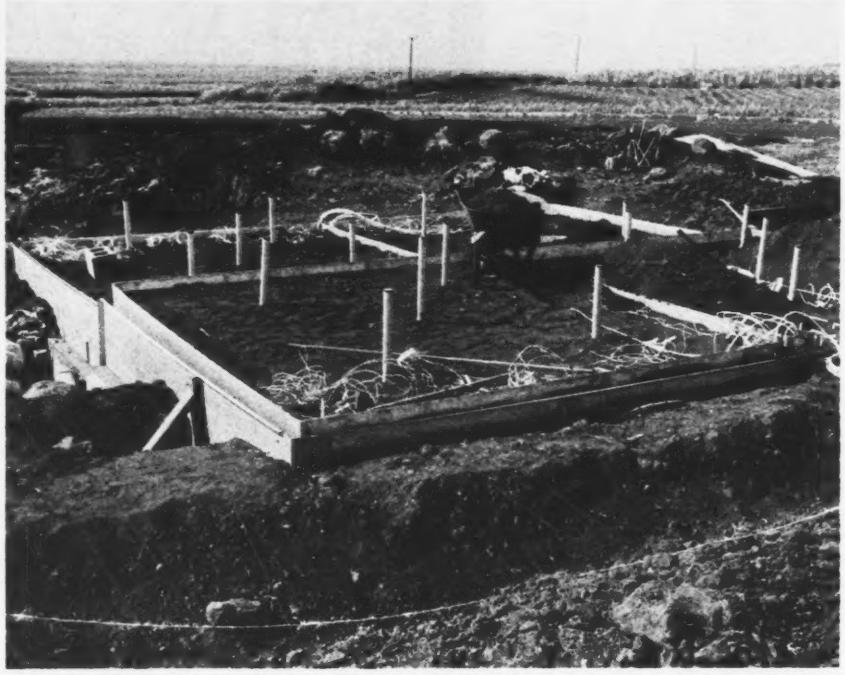
Bill Burley "amphicatting" across the ice-covered floodplain to take winter samples for Project B-025-ILL.

Photo, Courtesy Illinois State Natural History Survey

Experimental plot in North Carolina study of ground and surface water contamination from pesticide applications to cotton. Dr. Thomas J. Sheets of North Carolina State University is Principal Investigator. (A - 040 - NC)

Dr. B. Houston Atwell, principal investigator of project A-014-LA pulls up a bottom sample. He is studying planktonic life and its chemical environment as part of an overall investigation into pollution and ecological changes in Lake Pontchartrain due to storm drainage and flood control projects.

Mr. Coleman collecting a lake water sample. Photo, courtesy Department of Chemistry, Southern Illinois University



Building and installing field measuring devices such as lysimeter boxes can be hard work. These 10 x 10 boxes were loaded with fill soil after the installation of five neutron probes and boyoucos resistance blocks (the coiled 2 ply wires are lead lines from the blocks) in each box. Note the large boulders in the background which had to be removed during the excavation for the lysimeters. (Project No. A-014-HI)

Mechanical aerator tests feasibility of instream aeration of the polluted Passaic River, New Jersey. Photo, courtesy New Jersey Water Resources Research Institute

Control of Sediment

Statement of the Problem

Sediment originating in soil erosion and in construction activity has long been an important problem in water resources development. However, importance of sediments as pollutants is increasing, particularly in view of the ability of soil to adsorb pesticides and other organics including oily substances and to release these materials in the water resource. Indeed, this facility of sediments to receive chemicals from the solution phase, when properly understood, may be subject to manipulation and made to serve effectively to trap and immobilize harmful wastes moving in our environment. But man's intervention in sediment control must be based on sound understanding of ecological factors involved.

Numerous subject areas for further research for effective control of sediment include: methods of physical and socioeconomic evaluation of effects of sediment; physiochemical properties of sediment and its potential for trapping chemical and organic pollutants; and, effects of sediment on aquatic biota and eutrophication of lakes and reservoirs.

Research

Chemical contaminants found in surface and subsurface water as related to soil and climatic conditions were studied in Maine (A-006-ME). Results indicated amounts of insecticides in runoff were small compared to amount applied. Less than one percent of amounts applied were received in runoff. Concentration of insecticides was considerably higher in the soil or sediment fraction of the runoff.

Concentration and amounts of endosulfan, endrin and DDT were lower in runoff from a rotation system of potatoes, sugarbeets and peas than from continuous potatoes. In climatic areas where considerable runoff and soil loss may occur, an effective rotation system can reduce contamination from pesticides due to runoff. This study points out the importance of developing conservation practices that will reduce runoff and thereby reduce pesticide contamination of water resources.

An Iowa project (A-029-IA) involved study of a series of investigations to ascertain effects of channel curvature on depth-discharge relationships and sediment transport rates of alluvial-channel flows. Results indicate the energy gradient is only slightly affected by channel curvature, but rate of sediment transport is increased by a factor of 10 to 20. Hence it appears meandering is a means whereby streams increase the amount of sediment they can transport per unit of water discharge.

In a Vermont study (A-006-VT) an extensive evaluation was made of the Champlain Valley on amount and location of ground water supplies, sand and gravel resources, and areas where erosion could be a problem. This information has been mapped and is proving valuable for further resource planning and in evaluating the success of an erosion control program instituted by the SCS and Corps of Engineers in the Winooski River area in the 1930's.

A Missouri study (A-028-MO) has been started to establish feasibility of embankment protection--such as along irrigation canals--by use of a single graded filter layer in place of more common and costly multi-layered filter systems. The study is expected, also, to provide design criteria, furnish needed information of particle migration through and within a graded layer, and aid in establishing a mathematical relationship which will predict the filter layer performance.

Effect of dredging on nutrient levels and biological populations of a lake will be studied in South Dakota (B-013-SDAK). The study will be conducted on Lake Herman which has an area of 1,350 acres, an average depth of four and one-half feet, and six feet of sediment.

Included in the investigation will be an analysis of environmental factors before and after dredging such as phosphorus, potassium, nitrogen, sodium, pH, temperature, dissolved oxygen, alkalinity (Ca, Na) turbidity, phytoplankton, and zooplankton. Purpose of the three year study is to determine if dredging is an effective and efficient means of restoring dying shallow prairie lakes.

There is a special need to understand mechanisms by which waterborne wastes interact with soil. Fine soils and sediments are natural means to remove pollutants such as detergents, pesticides, radioisotopes and farm runoff. The objective of research in Georgia (A-002-GA) is to study particular interactions between water suspensions and soil minerals by passing radioactive material through sand aquifers. Analysis of data suggests removal rates could be predicted by use of existing physical theory and much higher retention by the soil could be attained.

Water quality and biological research investigations (A-021-MO) have been made in the "New Lead Belt" of Southeastern Missouri to evaluate effects of lead-zinc mining and mill wastewaters on stream environments. Natural background data were collected to establish baselines. Concentrations of heavy metals in tailing discharges were below limits of acute toxicity to fish but organic milling reagents served to contribute to growth of undesirable mats of blue-green algae (Oscillatoria) in receiving streams.

Suggestions for future stream pollution abatement in the mining area include (1) separation of mine discharge water from milling wastewater; (2) increased detention time for milling wastewater; (3) baffling or below-surface withdrawal of water from settling ponds to retain surface film of milling reagents; (4) removal of trees and heavy underbrush from settling ponds; and (5) continued research to determine improved methods of treating milling wastewaters. There has been close cooperation between the mining industry and the research workers. Baffles have been designed and will be installed on two settling ponds to test their effectiveness.

Geochemical effects of mining pollution in the stream of this area will be studied in project (A-023-MO).

Also, in Missouri fundamental sorption and desorption reactions of selected chlorinated hydrocarbon pesticides with clay minerals were studied (A-016-MO) in laboratory controlled environmental systems. The studies showed DDT, dieldrin and heptachlor were rapidly adsorbed on kaolinite and illite and equilibria were reached within less than an hour of reaction.

Project A-030-KAN is directed towards a fundamental understanding of the heavy metal content of Kansas rivers. Specifically, effort will be made to determine partition coefficients between "heavy metal" concentrations of stream water and suspended load; ascertain if seasonal effects are evident; determine the relation, if any, between mineralogical composition of suspended load and heavy metal concentration in solution; and, evaluate relationship of heavy metal content to geology of the terrain over which the stream flows.

A West Virginia study (A-008-WVA) investigated geochemical behavior of iron and manganese in a reservoir fed by streams containing acid mine drainage. Results, especially those showing vertical profiles of iron and manganese concentration by seasons, were used in selection of the intake level for a municipal water supply.

Nebraska project A-003-NEB, briefly reported upon in the OWRR 1968 Annual Report, is now completed and has produced interesting results on sediment control.

Investigators found the paralleled steep backslope terrace system with tile waterways is a conservation system which reduces water loss and greatly reduces soil loss on sloping land while being compatible with modern farming systems using high speed equipment. The conservation system also has potential to reduce flood hazards by reducing peak rate of runoff from agriculture watersheds and reducing the amount of sediment carried in waters downstream.

Steep backslope terrace systems offer potential of improving our environment by reducing nutrient content of runoff water. They can also be used to contain livestock waste applied to agriculture land without polluting the stream. Results indicate additional research is needed to fully evaluate the potential of conservation systems for improvement of our environment.

Prime sites for reservoirs in the United States are decreasing resulting in the tendency to construct reservoirs in areas with high siltation rates. An Indiana project (B-012-IND) has the objective of providing planners with tools and information for predicting soil stability from watershed characteristics.

Water Quality

Statement of the Problem

Normally when we think of water quality impairments, we consider sewage and industrial wastes. These sources of pollutants are not, however, the only threats to quality of the resource. In addition, the Nation's waters are impaired by: street wash of urban areas; runoff and drainage effluent from agricultural lands; feed lot discharges; sediment from eroded lands and construction activity: mine drainage; oily discharges; heated water discharges; and discharges from boats. These impairments are growing in sheer magnitude and few can yet be satisfactorily controlled.

A wide range of research is needed on: environmental effects of water pollutants; detection methods; methods of control; improved water management techniques; improved engineering works; and, methods of in situ cleansing of impaired water.

Research

Identifying Pollutants

As concern grows with respect to pollutants in the environment there is need to be able to detect elements and compounds which formerly were of little or no concern. Project A-013-KY deals with techniques for analyzing and detecting trace metals and organic materials. Flame emission spectroscopic studies are involved and techniques being developed will be used to analyze Kentucky waters for a number of trace elements for which no data are available. Companion Kentucky projects A-014 and 015-KY explored other techniques of identifying water pollutants.

Research study B-002-ARK deals with distribution of trace elements in selected Arkansas impoundments and factors influencing distribution of these elements. Investigations in the Ouachita River below Lake Catherine during late summer of 1968 showed a significant quantity of manganese was released into the river during power generation and that portions remained in solution as far as 25 miles below the dam.

Laboratory experiments conducted to supplement field studies of trace metals near the mud-water interface have provided considerable information on behavior of manganese and iron in relation to varying concentrations of oxygen and thermal stratification. It would appear manganese is present almost entirely in dissolved form in the oxygen deficient zone while a significant portion of iron is present in particular form. Results suggest that migration of reducing substances from bottom muds may account for essentially all oxygen consumption under the thermocline.

Objectives of a Massachusetts study (A-026-MASS) are twofold: (1) to inventory all species of vascular plants growing within the Mill River in Massachusetts or on its flood plain, and to carry out intensive ecology studies of these plants at selected sites along the river course; and (2) to determine microbial flora of the river at these selected sites.

Distribution and abundance of both macrofloras and microfloras within the river and its flood plain will be correlated with patterns of land use. Results will be available in the future when changes in diversity of flora or abundance or composition of its elements, may indicate environmental deterioration or improvement.

Michigan is continuing a study (A-023-MICH) on quantitative assessment of space and time variability of major water quality parameters in the Grand River System. Basic ecological investigations underway place particular emphasis on phosphorus and nitrogen pathways through the river system.

Pollution Sources

Extreme variations in concentration of pesticides in water and in various forms of aquatic life are shown in an Iowa research study (A-027-IA). Results indicated: Pesticide residues in water varied from trace amounts to a maximum of five parts per trillion; mud samples contained higher concentrations of pesticides than water; algal samples contained far higher concentrations than either mud or water; fish samples contained higher concentrations than mud or water; and dieldrin was the pesticide most frequently found in fish.

It was concluded that no generalization can be made regarding behavior of different pesticides in different environments. Concentration of pesticides in water depended upon a wide variety of factors. Highest concentrations usually occurred from July to October. Only trace amounts appeared from January to March.

In Kansas (B-007-KAN) an investigation has been made of relationships between pesticidal application and water contamination under irrigation in the Great Plains. Nine pesticides most commonly used in irrigated areas in the Central Great Plains have been applied on experimental fields in accordance with State and Department of Agriculture recommendations. Some pesticides have been applied for three years, others for four.

No confirmed, detectable contamination of well water was found at the 0.1 ppb (parts per billion) level, nor from total insecticide use in the irrigation district or entire drainage area. Deep soil core sampling demonstrated that insecticides penetrated the soil less than 12 inches.

Arkansas project B-012-ARK is concerned with quantifying nitrogen and phosphorus nutrients entering Beaver Reservoir in the northeast part of the State. Major sources of nutrients are being identified and their significance in eutrophication is being assessed.

Results indicate agricultural runoff was the major source of nutrients--both nitrogen and phosphorus. This was followed by domestic wastes and non-agricultural runoff, urban runoff and rainfall.

The purpose of a Rhode Island project (A-031-RI) is to develop criteria for study of water pollution in estuaries through aerial photography. Confirmation of water pollutants will be related to patterns delineated by serial photogrammetry of an estuarine area. Several types of cameras will be tested. It is hoped sensing methods developed will be useful in design aspects of water quality management programs for estuarine areas.

A Maine project (A-015-ME) is designed to provide information on parameters that control aging of lakes. The study will determine: (1) nutrient levels (nitrogen and phosphorus) responsible for nuisance algal conditions; (2) rate of change in nutrient levels in several lakes; (3) effects of removal of major sources of nutrients on algal conditions in lake waters; and, (4) effect of biological treatment of waste water on algal and aquatic plant development in lakes.

Results will provide management information useful in reversing the eutrophication process and restoring eutrophic lakes to their former usefulness.

In South Dakota (A-025-SDAK) pollution potential of runoff from livestock feeding operations is being studied. Continuous recording rainfall gauges and runoff measuring devices are being installed on large feedlots and self starting automatic samplers are being used. Analyses of samples and evaluation of data collected during runoff producing storms should provide sufficient information for appraisal of the pollution problem from feedlots due to rainfall. It is also anticipated that effectiveness of lagooning or other methods of solids retention can be evaluated.

Effects of Pollution

A study of open water distribution and abundance of net plankton as an index of eutrophication in Lake Superior has been completed in Minnesota (A-011-MINN). The study utilized a carbon-14 productivity technique and a continuous plankton recorder. Results have shown these methods to be effective for study of fauna and flora of the Great Lakes and for obtaining biological data relevant to productivity of water in the Great Lakes basin.

The continuous plankton recorder provides a means for assessing effect of pollution and ensuing eutrophication as reflected by studies of the second trophic level in a manner heretofore unobtainable; and, carbon-14 productivity studies proved effective in demonstrating that differences in primary phytoplankton production occurred in water masses of the Great Lakes system. Data accumulated in these studies will furnish valuable reference levels for persons interested in rates of eutrophication, productivity and water quality of the Great Lakes in future years.

A Maine research study (A-007-ME) evaluated effects of salt applications to deice highways on sodium and chloride levels in: (1) rivers and streams; (2) private water supplies contiguous to highways; and, (3) soils bordering highways.

Analyses indicated highway salting has no effect on sodium and chloride concentrations in rivers. However, semi-annual analyses of 100 randomly selected wells along Maine highways indicated sodium and chloride levels were much higher than normal. Twenty-five percent of the wells were found unfit for drinking water because they contained more than 250 ppm (parts per million) of chloride.

Sodium and chloride levels in soils contiguous to highways bore a direct relationship to length of time during which highways had been salted. Where salt had been applied for 20 years, sodium levels had increased for a distance of 60 feet from the edge of the highway, and to a depth of 18 inches. Sodium saturation of soil approached 15 percent at some sites. Chloride levels in the soil-water system produced equivalent of an "alkali" condition.

In West Virginia a significant portion of the research program is devoted to serious water quality problems caused by acid-mine wastes. Three projects (A-001, A-006, and A-017-WVA) have examined toxicity of such wastes to various fishes and determined effects on distribution, growth and abundance of fish species in the Monongahela River. It was found that fish species vary in their tolerance to acidity. The brown bullhead is most tolerant of West Virginia species. Since it is fairly abundant and favored by anglers, sport fishery management in acid waters is urged to focus on this species. These studies have been useful in establishing water quality criteria for conservation of fishes.

Other West Virginia studies (A-002, A-014, and A-018-WVA) investigated effects of acid-mine wastes on sewage microorganisms. It was determined that these wastes reduce sewage bacteria, extent depending upon the acidity. Yeasts and fungi assume part of the degradation function under such conditions.

Project A-011-WVA is concerned with tolerance and cytological response of algae to acid-mine wastes. No clear-cut results are available yet, but these studies will be continued in view of importance of algae as basic food in aquatic ecosytems and as producers of oxygen.

Algae are important as a nuisance factor in many types of water systems. To date control methods have involved use of chemical compounds such as copper which may be toxic to other forms of life. A Kentucky study (A-018-KY) is examining inhibitory compounds produced by algae themselves. These metabolic by-products of algae in mixed culture can enhance growth in some animal and plant forms while inhibiting growth in others. This line of study may provide clues to a biological method of controlling algae in domestic water supplies, recreational lakes and streams.

A Mississippi study (A-027-MISS) evaluated physical, chemical and microbiological changes that occur in fresh and brackish water during decomposition of crude and refined petroleum products and the effects of microbial by-products on fish.

Results, using both fresh water and artificial sea water, showed microflora caused marked physical changes in oil under both aerobic and anaerobic conditions. Disappearance of oil was more rapid under aerobic conditions, however, and addition of a nitrogen source and a supplemental inorganic enhanced microbial activity.

Waters in which microbial degradation of oils had taken place were toxic to fish even after separation and removal of bacteria and oil. These data suggest water-soluble products formed during microbial decomposition of petroleum products are more toxic to fish then was the original oil. Question as to whether concentration of microbial by-products in nature will be sufficient to affect fish must be determined by studies in the field.

"Eutrophication of Sheltered Bays in a Large Lake" is the title of Utah study B-010-UTAH. Three areas of Bear Lake were chosen for study, two protected by breakwaters, the third unprotected from wind-generated currents. Results showed that shallow regions in lakes protected from extensive water circulation go through a very rapid annual eutrophication cycle.

A Maryland study (B-006-MD) on water quality criteria to protect the fish population directly below sewage outfalls showed that of 98 secondary sewage treatment plants in the State, 37 discharged effluents into flowing streams containing fish life.

To test differences in water quality resulting from plant discharges, an upstream and downstream sampling station was established for each plant. Preliminary tests showed significant differences between the two stations, in certain water quality standards, especially conductivity and turbidity. Marked differences also were revealed in fish abundance, number of species, and diversity of species.

Investigation of 49 species of fish indicated great differences among them in tolerance limit to conductivity and turbidity increments resulting from plant discharge. Trout, darters, and most species of minnows appeared quite sensitive. American eel, white sucker, and most species of sunfish seemed to be fairly tolerant.

An Oklahoma project (A-010-OKLA) evaluated recent approaches for design of biological waste treatments. Results related to recent approaches for trickling filter design were presented at a training course for personnel of the Construction Grants Division of the Federal Water Pollution Control Administration. It was included as outline number 9 in their Training Course Manual entitled "Planning and Development of Wastewater Treatment Facilities."

Waste Treatment Process

A Delaware project (A-008-DEL) is investigating potentials for "pre-treatment" of sewage effluent, by aeration and activated sludge, in feed pipelines to sewage treatment plants. Preliminary findings indicate that utilizing "pre-treatment" processes might produce significant savings in total capital costs required for sewage treatment. Possibilities for a large-scale field testing of the process are being investigated and it is hoped this may be started within the next year.

A New Hampshire study (A-004-NH) conducted in collaboration with the New Hampshire Water Quality and Pollution Control Commission, demonstrated that perforated plastic pipes installed in the bottom of a 30-foot-deep lake, and connected to air compressors, could be used to destratify the lake and to change the algae population, thereby making the lake more attractive for recreational use.

Studies were conducted in Virginia (A-015-VA) to evaluate the coal contact process for removal of pesticides and phosphorus from wastewater. Because of cheapness of coal compared to activated carbon this process offers potential economies. Significant differences in sorption were found among four grades of coal. This process indicates that a high proportion of representative pesticides can be removed--lindane, parathion, and CIPO. In addition, it showed promising results in removal of phosphates when the system pH is in the range of 4.0 to 5.0 and the coal has an iron content.

A "seed" allotment project in Michigan (A-026-MICH) resulted in supplemental support from other sources related to recovery and identification of viruses in dilute suspension. Initial results showed almost all viruses suspended in river water could be recovered using concentrations of 50 parts per million of flocculant.

However, a study in Rhode Island (A-025-RI) on removing viruses from water by means of flocculants was more limited in its success. Encouraging results were obtained when AL(OH)3 was used to recover polio virus. But minimal success using this floc was obtained with NDV strain KM (a myxovirus), and an avian adenovirus (CELO strain Phelps) could not be retrieved at all. Results suggest that differential toxicity of flocs may be required for selective removal of viruses from water.

A South Carolina study (A-017-SC) is comparing costs of treating textile wastes in municipal and industrial sewage plants. The first phase on municipal treatment shows textile wastes can be successfully treated by biological processes if toxic wastes are first removed. However, less than 25% of municipalities levied a charge high enough to cover incremental costs. A field study is now underway on waste treatment facilities operated by textile manufacturers. Their waste treatment costs will be analyzed and compared to municipal costs for treating the same wastes.

Research in Missouri (B-017-MO) has been conducted on use of surface-active agents in a flotation process for removal of zinc, copper, nickel, and lead ions from water. Copper and zinc were effectively removed by this method. Some problems of precipitation were encountered with lead. Studies of effects of ultrasonic waves on surfactant solutions and flotation efficiency and further research on effects of pH on the flotation process are yet to be completed.

A Kansas study (A-031-KAN) is designed to determine if sludge produced by the lime-soda softener process can be utilized effectively in precipitating phosphate and suspended solids from raw wastewater. This use would not only help solve sludge disposal at the water treatment plant but would also permit significant financial savings in oxygen transfer in secondary sludge handling facilities. The project anticipates conduct of both laboratory and plant scale tests and preparation of an economic evaluation of the process.

Iowa study A-022-IA was concerned with hydrologic aspects of cattle feedlot waste management. Using the Iowa River Basin as a model, a method of determining required size of feedlot runoff control facilities, such as retention ponds, was developed. Precipitation, streamflow, and water quality data were analyzed and used to establish required size of runoff retention ponds for various management procedures.

Tests in another Iowa study (A-021-IA) using effluent from an anaerobic swine lagoon pointed up the value of soil in reducing pollution. Samples of effluent were analyzed for biochemical oxygen demand (BOD), chemical oxygen demand (COD), nitrogen, chlorides, phosphates, and pH. Effluent was applied as irrigation water on cropland containing a pipe drainage system to maintain favorable soil moisture conditions. Reduction in COD was excellent, ranging from 95 to 98% removal for individual treatments, with 97% average removal. Removal of nitrogen ranged from 79 to 83%, with an average of 80%. Chlorides were not significantly reduced by any treatments. All treatments proved very effective in removal of phosphates, each removing 99% or more of those applied.

Effects of application of sugar refining lagoon effluents on agricultural production and biological, physical and chemical properties of Fargo clay are being studied in North Dakota (A-019-NDAK). Initial results on alfalfa and sudan grass indicate no significant difference in crop yield from plants irrigated with effluent compared to those with water. It appears soybean tests, now in process, will show no significant difference. Although preliminary, results are encouraging that this method will be a practical means of effectively utilizing sugar refining lagoon effluents without polluting surface or ground water.

In Alabama project A-012-ALA investigators are evaluating, through laboratory research, gamma radiation of textile wastewater as a pollution control measure. Waste solutions of particular interest were those derived from desizing and textile dyeing operations.

Preliminary results indicate that viscosities of sizing solutions are reduced by the process. Sizing solutions which originally were basic (pH9-10) may be neutralized and rendered acidic. Where sizing compounds are polymers, the degree of polymerization is reduced. However, chemical oxygen demand (COD) appears to be unchanged. Also, although certain of the dye compounds are decolorized, some vat-type dyes are unaffected.

In Colorado (A-007-COLO) studies will be initiated to isolate and identify microorganisms present in sewage treatment systems in the cold environment of high mountain communities. Bench studies will be initiated to determine optimal microbial flora for waste digestion at temperatures between 0 and 20°C,

The Pennsylvania Water Resources Center has done significant work on spray disposal of sewage effluent. Past studies produced promising results for utilizing sewage effluent to neutralize acid mine drainage and for applying sewage effluent to crop and forest lands on a year-round basis. Project B-020-PA is pursuing another aspect of spray disposal effluent to neutralize highly-acid spoil banks and replenish ground water supply. Results of this and allied prior projects have led to their practical application in the forthcoming construction of a system in the Pennsylvania State College community that will dispose of 4 million gallons of sewage effluent daily by spraying it over land areas.

An Alabama project (B-019-ALA) is contributing to the knowledge of deep-well liquid waste disposal methods. Principal investigator, Dr. David M. Grubbs, reports that in the Coastal Plain several potential zones have been identified which have parameters favorable for disposal of vast quantities of liquid waste where there is no risk of contamination of potable ground water. Basic factors studied were volume of pore space in various underground reservoirs that would accommodate liquid waste and presence of impermeable barriers to prevent contamination of the fresh-water resource. The remaining portion of the study will center on possible long-range effects of injected liquid wastes.

Water Treatment

Missouri study A-015-MO shows promise of providing a method for improving existing procedures for removing solids from waste water at a lower cost than methods now in use. Separation is attained by forcing a two-phase flow through a constriction in a pipe. Solids follow path lines different than fluids. The device is described as self cleaning, thus reducing frequency of cleaning sedimentation tanks needed for secondary separation. Further research is being accomplished with non-OWRR funds.

A Wisconsin study (A-020-WIS) on experimental reversal of the lake eutrophication process was suspended after one year until information could be obtained on a more basic question: Is there a measurable relationship between heat input to nutrient-rich aquatic systems and output of harvestable biomass? This question will be the subject of a separate research study which will explore effects of thermal inputs on biological production in nutrient rich ponds.

Water Quality Control

Several North Carolina projects (A-035, A-036, A-032 and A-037-NC) deal with various aspects of industrial water use and waste control. Water quality problems from industrial wastes in North Carolina come largely from textile, pulp and paper, and food-processing industries. The practice of dealing with industrial wastes primarily as treatment problems inflates costs of remedial action. Waste treatment is expensive and should be a last resort. The studies show that such alternatives as more efficient water use, chemical substitution and recovery, process change, waste by-product development, and other internal means offer many possibilities for substantial cost savings to industries involved. Because of demand for decrease in waste discharges by industry in the face of rising production, every effort should be made to eliminate wastes at point of origin as well as to forge ahead with development of improved treatment techniques.

The basic objective of a recently initiated Nebraska study (B-003-NEB) is to determine the maximum allowable rate of loading livestock manure on cultivated soil without pollution of surface runoff or underground water. Other objectives are to determine:

(1) magnitudes of surface and ground water pollution which can result from high rates of manure application on surface irrigated lands,

(2) changes in physical and chemical properties of soil resulting from high rates of manure applications on surface irrigated lands,

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(3) effects of very high loading rates on crop production,

(4) economic feasibility of high rates of manure application on surface irrigated land, and

(5) to compare costs and benefits of higher rates of manure application on surface irrigated lands to costs and benefits of various alternative means of utilization or disposal of manure.

Project A-022-MASS conducted a survey of community leader attitudes on water pollution problems in Massachusetts. Community leaders of varying backgrounds agreed on the importance of water pollution problems and need for a cooperative regional approach in attempting to solve them. They agreed regional problems had not been alleviated and tended to believe State and Federal authorities had not been active enough in abatement work. They differed regarding the priority of water pollution problems as among other pressing social and environmental problems.

The project is significant to water resource planners by pointing out many diverse and often hidden factors that shape attitudes and traditions. These factors must be taken into account in developing planning goals.

Pollution of ground water in areas of increasing population densities where municipal sewage systems are non-existent poses a potential threat to an existing water supply. A Rhode Island study (A-032-RI) will determine the legal right to protect underground water supplies under the following conditions; (1) when it is being contaminated while in use as a water supply; (2) when it is contaminated but not used presently as a supply, but could provide future supply (preservation for use) and, (3) where future planned-use of land threatens underground supply. In addition, the study will attempt to determine "savings" that can accrue to a regional water basin by maintaining a high degree of purity in ground water deposits in the region by removal of waste water through a sewage treatment system. Also, considerations of costs of treatment of ground water as an alternative to protection of the supply by a sewer system will be undertaken.

An exploratory research program in Connecticut (A-028-CONN) is undertaking to identify major legal problems relative to lake pollution in the northeastern United States. Preliminary investigation has shown need for determination of applicability of general pollution control laws to lakes. Need also exists to establish criteria for formulation of policies and methods for enactment of legislation, and to identify changes needed in statutory law and administrative structure to facilitate greater protection and utilization of lakes.

A study of effects of impoundment reservoirs on river water quality, including analysis of chemical and physical characteristics of water and up-take of nutients by aquatic life, is being conducted in Alabama (B-010-ALA). Of the 11 most abundant elements being investigated, preliminary results indicate that only one, phosphorus, is being retained to any great extent--probably in the hydrosol or mud-water interface--in the impoundments. All other elements apparently are passing through the reservoir system at a rate comparable to what the Chattahoochee River would normally carry were it not impounded.

A Maine study (B-003-ME) has demonstrated technical feasibility of managing a river system as a chemical reactor that is self-purging of oxidizable organic matter. The scheduled input of organic matter is guided by a continuous monitoring of the chemical kinetics profile of the Penobscot River system in a 25-mile reach from Bangor Dam to the tidal basin. A pilot model of instrumental systems for continuous monitoring, transmission, and processing of selected data, including dissolved oxygen and BOD, has been designed, constructed and evaluated. The stage has been set to allow extension of these results to other rivers by development of a control system independent of particular details of the river model.

The pollutional effect waste discharge from small pleasure craft has on bacteriological quality of otherwise unpolluted water of two small harbors is being investigated in the State of Washington (A-024-WASH). With anticipated increased use of similar harbors in the future by pleasure craft, water quality degradation can be expected. Results are expected to aid the Federal Water Pollution Control Administration in formulation of an effective control program for sewage from vessels and in assisting the Washington State Board of Health in establishing local regulations to help control the problem.

Pollution of streams by acid mine drainage is a serious and common problem in Pennsylvania, and in the rest of Appalachia. In project A-002-PA extensive laboratory study was made of the potentials of limestone barriers for neutralizing acid streams. Results were so promising that the Pennsylvania Department of Mines and Mineral Industries is currently designing a prototype limestone barrier for use in one of their polluted streams. It is expected to go into operation by mid-1970.

Meeting Increased Water Supply Requirements

Statement of the Problem

The total quantity of fresh usable water is relatively fixed (or perhaps decreasing) while demands upon this supply are increasing exponentially with time. An increasing number of areas are already facing the problem of demand exceeding supply. What steps can be taken to avoid limitations on future economic growth which may be brought about by water shortages?

In general, solution to this problem involves (a) increasing fresh water supplies, (b) conservation in use of water and, (c) redistribution of supply in time and space. The problem is so broad and complex that almost all-water related research is relevant to its solution. Research is needed to develop and improve techniques in: Conversion of salt and brackish water; cloud seeding; increased yield from catchment basins; treatment to reduce infiltration and evapotranspiration; more efficient use of existing supplies; and, developing the potential and criteria for transbasin transfer.

Research

The object of project A-016-NY is to take a "fresh" look at wastewater treatment in light of growing interest in reclamation of wastewaters as a "new" source of water. This reevaluation of wastewater treatment technology is intended to lead to development of a rational approach to optimal design and operation of wastewater treatment systems. Identified categories of water reuse include irrigation, groundwater recharge, impoundment for recreational purposes, industrial water, municipal water, and discharge of reclaimed (treated) wastewaters to natural watercourses. Particular emphasis in this New York study is being given to wastewater discharges into natural waters because considerable uncertainty still exists as to acceptable concentrations of phytoplankton nutrients in natural waters.

Project B-041-TEX studied development of systems for ground water recharge into the Ogallala Formation in Texas. A relatively new or modified method of recharge has been developed from the research. Preliminary tests indicate the method referred to as "hole" recharge, possesses potential for two reasons; one, respectable rates of recharge can be attained at a low initial cost; and, two, sediment does not have to be removed to attain and maintain these rates.

It was also determined that pits still possess potential as long as water level is such that a large percentage of the wetted perimeter of the pit is found in the sidewalls. Pits must have a bottom dimension which is relatively narrow.

Results should prove useful in providing an effective means of water recharge where ground water plays an important role as a major source of water supply.

An outstanding facility for study of natural evaporation and evapotranspiration processes and associated micrometeorological phenomena was developed at the University of Nebraska Field Laboratory at Mead (A-001-NEB). Precision weighing lysimeters and equipment for measurement of components of radiation balance; air, soil and surface temperature; and atmospheric humidity were developed and tested. Computer programs were written for conversion of field data to parametric forms.

Findings indicate advection is an important source of energy for driving the evaporational processes in the eastern Great Plains. Evaporation from bare soil and evapotranspiration from alfalfa often exceed radiant energy input; sometimes by as much as 80 percent. Results are directly applicable to design of effective water conservation practices for agricultural production in the Great Plains area.

A similar study in South Dakota (A-018-SDAK) is designed to better understand and improve soil-plant environment for more efficient utilization of water. Evapotranspiration rates for grain sorghum and other crops are being determined by lysimeter and water budget methods. Evapotranspiration values being obtained by this study are being used to establish base rates for use in an irrigation guide for the State.

Also, in Nebraska a study (A-015-NEB) is being conducted on physiological and biochemical responses of plants to different internal water potentials. Objectives of this project are: (1) To investigate biochemical effects of internal water stress on some physiological (biochemical) processes such as photosynthesis, respiration and dark fixation of carbon dioxide during stress and recovery period; and (2) to investigate mechanisms by which plant water potentials and water use (transpiration) are controlled or influenced by plants.

Influence of mid-day mist irrigation on reduction of environmental water and temperature stresses and on growth and development of potato plants were studied in Minnesota (B-013-MINN). Temperatures throughout the plant canopy, plant temperatures, and soil temperatures were recorded. While results of these measurements are still being evaluated, it can be reported that mist irrigation reduced leaf temperatures by 2 to 16°C.

Reduction of temperature and moisture stresses by mist irrigation resulted in increased potato plant growth and increased total yields of tubers. Tuber defects such as hollow heart, growth cracks, and secondary growths were increased by misting but in spite of these defects yields of U. S. #1 grade tubers were higher than from non-misted plants. Chipping quality of tubers was decreased, an effect that is being studied further. Results offer promise of more efficient utilization of irrigation water, accompanied by increased yields.

A project in New Mexico (C-1361) is involved in study of water requirements for salinity control in unsaturated soils. The research has produced encouraging evidence that amounts of leaching water recommended for salinity control can be revised downward. Relatively large volumes of water are moving through the soil even though soil moisture content is low, and the water is effectively removing salts. Potential saving of water in this water short area could be of considerable significance to the agricultural economy of the state.

A study (A-025-MASS) of a different nature is being conducted in Massachusetts to determine methods of more effectively meeting increased water requirements. A legal and economic evaluation of ground water doctrines is being made by analysis of court decisions and examination of current practices and procedures used by the Massachusetts Attorney General and other State Agencies. The analysis will provide a basis for determining the nature and extent of inequity in ground water use, and for estimating the associated magnitude of economic impairment. Legal and economic concepts of equity currently applied to the ground water resource will be contrasted. Objectives are to: (a) evaluate the consistency of statutory and common law applicable to ground water resources in Massachusetts, (b) assess economic effects of these laws on water users; and (c) determine effects of these laws or use patterns with regard to water quality, diversion, discharge, obstruction, and multiple-use.

To determine the most productive use of irrigation water from ground water sources in Idaho, an investigation (B-006-IDA) has been underway since 1967 to establish relationships between pumping lift and the price farmers can afford to pay for water. It has been shown that in Cassia County, Idaho, under average conditions at an irrigation efficiency of 55 percent--water can be economically lifted from a maximum depth of 389 feet for a 200-acre farm; from 679 feet for a 400-acre farm; and from 767 for a 600-acre farm.

The investigation is being extended to encompass a greater portion of the state. However, results are already being used by the State Reclamation Engineer to establish reasonable levels of pumping lift in administration of state ground water laws.

The economic impact of theoretical transfers of water from "surplus" to "deficient" regions is being assessed in research activity in Oregon (A-002-OREG and C-1220). To justify diversion of water from one area to another it is theorized that the lowest valued use of water in the receiving area must exceed cost of transferring the water plus value of the water if used in the area of origin. A report is now in preparation providing an economic evaluation of a theoretical diversion of water from the northwestern to the southwestern part of the United States. Further work involves describing income redistributive impacts of interbasin water transfers. Results of this research are expected to serve as a significant contribution to informed and rational decision-making concerning the issue of water diversion.

In Wyoming considerable effort (A-001 and B-002-WYO) is being made to define considerations that must be taken into account when planning for possible trans-mountain diversions of water from the Green River Basin to the Platte River Basin in Wyoming. Considerations include: Present and future demand for water; legal constraints on diversion; augmentation of present supply of water by methods other than trans-mountain diversion such as weather modification; and capital investment involved in implementing diversions. In establishing present and future demand (value) of water in its present setting in the Green River Basin, a detailed investigation is underway to determine present and expected future value of game and fish resources of the Green River Basin that would be affected if large water diversions are made from the Green. Information obtained will be of significant value to planners and decision makers concerned with diverting Wyoming's waters.

Few studies have investigated individual plumbing fixtures in respect to water consumption and/or pollution load. Project A-025-CONN in Connecticut is a study of initial sources of pollution or wastes that are generated and mixed through the plumbing arrangement in a household. The project is intended to show relative importance of water use by each fixture and would indicate potential gains to be made if water conservation measures by new plumbing fixtures were initiated. The project will also be useful in identifying impact on water use of new household water and wastewater appliances in designing appropriate wastewater disposal systems for residential use.

Use of water reservoirs in urban areas for flood control, with projected multiple-use benefits of water conservation, reduced costs and multi-use reservoir benefits, has been the subject of research under project C-1187 conducted by North American Rockwell Corporation.

The project analyzed multiple benefits and costs of installing a water reservoir system in urban areas in lieu of conventional storm sewers. Benefits of proposed uses of reservoirs were evaluated for a representative urban site using actual economic, engineering and benefits data accrued at Santa Maria, California. Dual-use benefits of land employed for urban reservoirs were a major consideration and included recreational aspects as well as parking structures and influence on urban land and building values.

Results indicate favorable competitive installation costs of a reservoir system for flood control as compared to storm sewers, with substantial additional benefits provided in water conservation and multiple activities such as recreation, parking and other uses. Additionally, the modular aspect of water reservoir systems, providing for independent installation and drainage of individual land areas, provides for phased construction and financing for urban flood control over a prolonged time period reducing long term commitment of funds. This procedure is often desirable in eliminating bonded indebtedness for flood control purposes.

A number of urban areas have demonstrated interest in this water reservoir approach to flood control. Further application of a demonstration project is being developed by the city of Santa Maria.

Information from a Puerto Rico project (A-005-PR) will be most useful in conserving water used in irrigating sugarcane. Experimental results show that 20 inches of water per acre can be saved without affecting sugar yields if sugarcane is irrigated frequently during the first part of the growing season and irrigation is stopped five months prior to harvest.

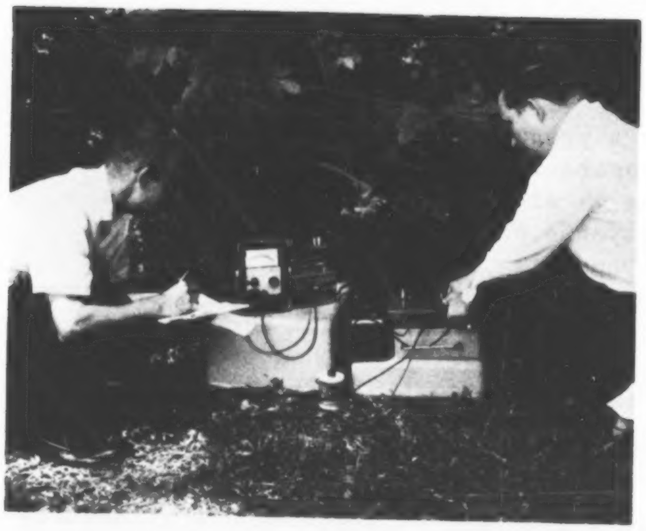
Evaporation from lakes and reservoirs is a major loss of fresh water that is needed for the expanding economy of farms, ranches and industry of the Southwest, where water supplies are stored in above-ground reservoirs. Research over the last decade has shown these losses can be reduced by about 35 to 40% by applying a chemical film of hexadecanol or octadecanol to the reservoir surface. However, wind removes the film from the surface unless the chemical film is continuously replaced. There is need for studying other methods of evaporation control which would not be affected by wind. Oklahoma project (A-014-OKLA) will evaluate floating covers of various solid flexible materials. For small reservoirs these materials may have a greater efficiency than chemical liquid type films. Of particular interest is the relative efficiency of floating covers which cover only a portion of the reservoir.

Mitigation of Water-Caused Damages

Statement of the Problem

Any discussion of water resources goals and beneficial uses must also give proper consideration to water as a "negative resource." Despite many billions of dollars invested in flood control works, flood losses continue to rise. This has resulted from progressively more intensive agricultural, industrial, and urban/suburban development of flood plain lands, which offer many advantages from the standpoint of fertility, transportation/communications/utilities, and other or adjacent prior development.

Research in this problem area involves non-structural flood control measures such as development of improved techniques of planning, managing, zoning, and insuring of property on flood plain areas. Also involved is research on improving traditional methods of controlling floods through various types of engineering works.



Measurement of electrical resistivity and electrical induced polarization with the Wenner configuration in the Clemson Research Watershed. This study is evaluating the effectiveness of these geophysical methods as an aid in the determination of subsurface hydrogeologic environments in the Piedmont area of South Carolina.

Dr. T. L. Drake (on left) is recording the measurements performed by Mr. W. Freeman (on right). (Based on Project No. A-011-SC).

Photo, courtesy of Clemson University

Professor J. D. Womack and Dr. Remy L. A. deJong placing a Savonius rotormeter in the reservoir. This meter is being used to determine the velocity of the water in terms of magnitude and direction. Photo, courtesy Tennessee Center

Dr. Larry Boersma, Soils Department, Oregon State University, examines a test plot of corn planted for his research into use of heated water from nuclear plants for agricultural purposes. The corn on the right has received heat from pipes buried in the soil to simulate a closed system of hot water circulation. Photo, courtesy Oregon Water Resources Research Institute

Mechanical soil sampling in Kansas for the measurement of nitrate nitrogen. Project A-016-KAN.

Research

"The Urban Snow Hazard" is the title of a project (B-032-ILL) at the University of Illinois being conducted in cooperation with the University of Toronto which will study snow hazard problems in eight widely dispersed cities in the United States and Canada. Expected payoffs of the study are two-fold. First, through the measurement of costs and benefits incurred by a city because of snow, an estimate can be formulated concerning the optimal snow removal program under variable amounts of snow and economic bases of urban areas. Secondly, through study of the decision-making process in formulation of snow control programs, obstacles to operation of a more effective snow control program will be identified. Results will be useful to decision makers for improved planning and a better means of determining how much a city should spend on snow control.

Another study in Illinois (A-030-ILL) is evaluating progress of non-structural methods for flood plain management in the north central, midwestern States. Results to date indicate few communities in this region have attempted regulation of flood plains through zoning, even though planning agencies have repeatedly emphasized importance of placing flood plains in a special district. A partial result of the study has been development of a legislative proposal for establishment of a State Commission on Flood Plain Regulation to study non-structural alternatives at the State level and their incorporation into programs of flood control projects.

The study has identified approximately forty methods that may be useful in non-structural flood plain regulations. A list of some principal measures include (1) flood plain zoning, (2) land fill in flood hazard areas, (3) flood hazard non-conforming uses, (4) open space land acquisition programs, (5) public health requirements (pure waters legislation), (6) loss bearing (those who suffer the damage pay for the loss), (7) land banks (land is purchased and held until the State or other semi-public agencies can purchase or lease the land for public conservation or preservation purposes), (8) tax rates on flood hazard areas, (9) flood hazard relief and rehabilitation, (10) flood hazard regulation through the formation of a state planning agency or department of natural resources, (11) deed restrictions and covenants, (12) flood hazard rescue operations, (13) flood hazard forecasting services, (14) flood hazard regulation by utility extension, (15) flood hazard subdivision regulations, (16) flood hazard land values, (17) flood hazard insurance, (18) flood-proofing of structures, (19) flood hazard design criteria, and (20) site design criteria.

A case study analysis and appraisal of these various alternatives is a major objective of the continued study. In addition, measurement of local reaction of acceptance or rejection of pre-planned alternatives will be made where serious flood plain problems are known to exist.

The objective of research in Georgia (C-1323) is to design a methodology for developing and testing instruments needed to evaluate alternatives in flood plain management. The work has demonstrated that water management must recognize social and political elements of the problem as well as hydrologic and engineering aspects--not only recognize them but relate engineering management to these social elements.

One question being tested is: Why is an urban flood plain persistently occupied by resident householders and business? Five factors have been identified: economic, low visibility of hazard, social, aesthetic and ideological.

In addition to economic factors being evaluated a device has been developed and pre-tested to rank determinants of residential locational decisions within and outside the flood plain. Social, aesthetic and ideological factors and values will be probed through survey research. Survey research has also been directed toward measurement of citizen perception by means of a semantic rating scale.

Results of this research will provide information for setting guidelines as to how water in urban areas can be used to improve quality of life in the city. It will show how contervailing forces may be assembled to preserve floodways and watersheds against interminable forces of private economic development.

The economic impact of flood control reservoirs has been under continuing study by the University of Kentucky Institute since 1966 (A-006-KY). The study has multiple objectives. Some examples are: Effects of large flood control reservoirs on local employment patterns, changes in land use, economic losses from inundation of valuable land, reservoir-related income distribution resulting from the reservoirs, and improved reliability of recreation benefit estimates under different types of reservoir management. Thirteen major study areas have been undertaken, six of which have been completed and final reports written. Demand for these reports have exceeded supply. Major Federal water planning agencies have shown special interest in the reports and the Tennessee Valley Authority is making a serious attempt to apply project findings in the development of an improved reservoir operation scheme.

A companion study in Kentucky (C-1282) was initiated in FY 1969 and is concerned with computer analysis of watershed characteristics affecting flood hydrology. Results should provide a better understanding of how and why small watersheds vary hydrologically and how they change with varying land use. Possible applications include more accurate selection of designs for culverts and urban drainage measures and better planning with respect to flood control for areas inundated by runoff from small urban watersheds.

Conserving Ecologic Values in Water Resource Planning

Statement of the Problem

The significance of adverse side effects that could result from man's use of his water resource has increasingly impressed the planner with the need to view proposed developments with an ecologic perspective. For example, the chain of events from lamprey to alewives infestation of the Great Lakes reflects failure of planners of the Welland Canal to foresee the importance of ecologic studies in the project design. This and many additional examples emphasize the need to improve our ability to anticipate unwanted side-effects of water resource development, and to include studies for this purpose as an essential part of the planning process.

The need for improved techniques for predicting the response of water-related biological communities to man-induced environmental change is fundamental to planning for resource use. The variety of such man-made environmental change is great indeed, and it emphasizes the need for systematic, reliable study procedures. The research challenge is formidable and support for such research merits high priority.

Research

Effects of chlorinated hydrocarbon insecticides on fresh water seed shrimp were studied in South Dakota (A-015-SDAK). It was determined that from 1 to 10 parts per billion of aldrin and dieldrin in water will virtually kill 100 percent of the seed shrimp. Exposure of shrimp to sublethal doses does not appear to build up resistance. There is some indication that with constant exposure seed shrimp become more sensitive rather than resistant.

At concentrations near the lethal limit, aldrin and dieldrin are rapidly accumulated from water by seed shrimp. After 24 hours of exposure seed shrimp concentrate up to 1,800 and 1,600 times respectively the aldrin and dieldrin concentrations in the water. The seed shrimp body per se accumulates most of the residue, probably through the respiratory structure. Movement of insecticide in live shrimp is entirely one way; there is practically no active or net excretion. However, dead shrimp tend to return much of their accumulated insecticides to the water.

The pesticides result in toxic residues concentrated in the region of the mud-water interface. Benthic organisims such as seed shrimp which live on the pesticide-laden substrate, because of their indiscriminate filter-feeding habit, may function as "recyclers" of otherwise dormant insecticidal residues. Reintroduction of residues into the ecosystem and subsequent transfer to higher links in the food chain may pose a serious threat not only to higher aquatic animals but also to terrestrial animals which derive use or benefit from both aquatic life and water itself.

A South Carolina study (A-013-SC) is also concerned with pesticides in the aquatic environment. In a flowing system, experimental golden shiners exposed to carbon-14 labeled DDT showed concentrations of DDT and metabolites 10,000 times above the level added to the water. Fish fed pelleted foods with known amounts of added DDT showed uptake of more than 50 percent.

"The Uptake and Concentration of Fluoride by the Blue Crab, *Callinectes sapidus*," is the title of a North Carolina project (A-030-NC). The study has contributed further information on ecological effects of increased fluoride levels in the Pamlico Estuary as a result of phosphate processing. Special attention was given to fluoride accumulation in crab tissues and to the effect of fluoride on crab growth. At 20 ppm fluoride in the water, the growth increment of crabs decreased 4.5 percent per molt. The cumulative effect over a 20-molt life cycle of a typical blue crab would be a 52 percent reduction in final average size. Fluoride concentrations higher than 20 ppm had an even greater inhibitory effect on growth. Exposure of crabs to water with 200 and 400 ppm fluoride for extended periods showed crab muscle tissue can accumulate enough fluoride to present a potential public health problem.

The Delaware River Basin Commission has provided most of the matching funds for an important New Jersey study of "Effects of Thermal and Other Forms of Pollution on Some Anadrhonous Fishes," (Project B-012-NJ). This study is providing useful information as to vulnerability of key species of fish to specific pollution hazards.

Effects of DDT on the ecology of a water-dominated environment is being investigated in the Flathead Lake area of western Montana (A-016-MONT). DDT-based insecticides are used extensively throughout the area for control of insect pests of cherries. Results to date show that disturbing quantities of DDT are present in fish and wildlife species of the area and some evidence has been found showing lethal levels of contamination have already been reached in some species. For example, the osprey population appears to be declining in the Flathead Lake area because of DDT contamination. This contention is supported by presence of from 37 to 59 ppm of DDT residue in a number of addled osprey eggs containing well-developed, but dead, embryos. Data also indicate that high enough levels of DDT may be present in migrating kokanee salmon to affect eagles in the area that utilize spent salmon for food.

In a South Dakota project (B-002-SDAK) the Lake Poinsett ecosystem was analyzed for chlorinated hydrocarbon residues. Components analyzed were water, bottom sediment, plankton, algae, crayfish, aquatic insects, and fish. Concentrations of nine insecticides were determined by gas and thin layer chromatography.

Results showed DDT and its metabolites to have the highest residue levels in all trophic levels examined. Heptachlor, heptachlor epoxide, aldrin, dieldrin and lindane were present in the majority of sample types. Endrin and methoxychlor were not detected above analytical confidence limits in any sample while toxaphene was found in four fish. The DDT complex was found to increase in percentage of total residue with higher trophic levels. A change in ratio of DDT to DDD plus DDE was found with increase in trophic level with amounts of DDT being greater the lower the trophic level. Water had the lowest total residues. Bottom sediment and crayfish had 18 times the water levels, plankton and algae a 37-fold increase, fish a 790-fold increase and aquatic insects a 7300-fold increase. The amount of insecticide significantly increased with age of the fish and amount of fat in the fish. The DDT complex residue levels were well below the recent tentative Food and Drug Administration's tolerance limit of 5 ppm on a whole-body, wet weight basis.

Results of this study demonstrate the increase of chlorinated hydrocarbon insecticide residues with increase of trophic level in aquatic ecosystems. Future planning on water quality control in South Dakota should consider both the persistence and build up of insecticides in lakes and streams. Future direction of this project will be on insecticide analysis of fish-eating birds which summer in this area.

With passage of P. L. 90-542, The Wild and Scenic Rivers Act, the Nation has shown its concern about unrestricted river development that provides little or no attention to maintenance of a quality environment. To provide planners with a tool for use in future planning involving undeveloped river stretches, the State of Idaho is conducting an investigation (B-014-IDA) to develop a methodology for evaluation of wild and scenic rivers. This study is expected to: Identify and estimate present and future quantities and values of natural resources in selected study areas; describe and quantify as far as possible benefits derived from esthetic values and personal enrichment from river areas; develop a model for evaluation of alternative uses of related resources of the areas and, present recommendations for alternative use and development levels for wild river areas.

In Massachusetts an interdisciplinary research study (B-012-MASS) is being initiated involving classification of wildlife values, a study of aesthetic values, and an analysis of economic values of wetlands. By aerial photography selected wetlands and watersheds will be mapped and subsequently compared with similar maps now 18 years old. Quantitative and qualitative descriptors will be prepared for computer analysis of change in wetlands over this time interval and some predictions of future change will evolve. A geological framework for wetlands will be developed to assess involvement of given wetlands in local groundwater regimes. Indicators of wildlife values will be developed to evaluate effects of wetlands changes on wildlife. Visual-social values of wetlands will be studied to determine roles these land types play in aesthetic contributions to the general environment. Broad economics of wetlands, including costs and benefits, traditional and aesthetic, will be studied to provide a value base to aid in management decisions. Results should be of substantial value in developing usable criteria for evaluating values and uses of wetlands and in determining amount and location of wetlands that should be preserved.

In Illinois, findings from project B-025-ILL indicate that flood plain pools play an important role and could play an even more important role, in fish production in the Kaskaskia River. Zooplankton populations, composed of microcrustaceans, protozoans, and rotifers are generally ten times greater in flood plain pools than in the river. Since most young fish feed almost wholly on zooplankton at some stage in their development, it would be advantageous for fish to move into flood plain pools to spawn. However, flood plain pools are dependent upon proper weather conditions to maintain water levels adequate to keep connections with the river. Below normal precipitation could destroy fish reproduction in the pools for the year. Illinois scientists believe managing water levels in the pools artificially rather than depending completely on nature could greatly increase fish population in the Kaskaskia River.

Ohio project (B-017-OHIO) deals with the relation of on-shore economic activity of the western basin of Lake Erie to pollution inputs. Systems analysis visualizes the system as comprised of two major subsystems, economy of the Detroit-

Toledo metropolitan area, and in-lake ecological subsystem; and two related subsystems, geological effects and recreational demand. A conceptual model is being developed to describe the ecological system primarily in terms of oxygen transport and utilization.

An imaginative approach to understanding the dynamics of a natural stream system has been taken in a Michigan study (A-032-MICH). Because streams are threatened by increases in nutrients and pollution, it is essential that we establish baseline populations for normal, unmodified streams. In this way we may recognize subtle but possible extremely important changes in streams as a result of land-use practices and nutrient runoff. Findings indicate trophic structure can both define the nature of a stable stream ecosystem and predict as well "sensitive" points in the system, such as population levels or level of food source. Measurement or prediction of trophic instability should prove to be a powerful tool in water quality studies, particularly during subtle transitional stages when corrective measures might be possible.

Metropolitan Area Water Systems

Statement of the Problem

The continuing growth of population and industry in urban areas and the coalescence of communities are creating important problems in all aspects of metropolitan area water systems. Examples of areas where research is needed are: costs and benefits of various scales of facilities; the planning process with socio-system simulation incorporated in the research; the preferred institutional framework within which metropolitan water planning and management should take place; ways to measure or evaluate social efficiency compatible with those existing for economic efficiency; and the relationship between technological change and social change, and effects in the past of one on the other. Also, studies are needed on policy changes to lessen or remove legal, political, jurisdictional, administrative, planning or other non-engineering impediments to more efficient and effective water resources planning.

Research

Deliberate and systematic study of urban water problems on a comprehensive basis has long been neglected. The American Society of Civil Engineers is assisting the Office of Water Resources Research in outlining and developing a national program of urban water resources research. The objective of the research project, headquartered at Harvard University, is to provide guidelines for initiating and expanding a program of long-range studies in urban water problems.

A final report (C-1125) for the first project year has been published comprising nearly 700 pages. The report points out that National capital investment in principal components of urban water service is over $110 billion with projected construction costs of more than $7 billion a year for the next several years. All factors considered indicate total expenditures by local governments on urban water will average $12 billion or more each year through 1980. Among subjects also covered in the report are:

1. Prefeasibility studies to determine possible effectiveness, cost and time requirements for: (a) a comprehensive systems engineering analysis of all aspects of urban water (two studies); (b) a general economic analysis of cost and pricing parameters of all aspects of urban water (two studies).

2. A state-of-the-art study of mathematical models and related simulation methods potentially usable for analyzing urban rainfall-runoff-quality processes.

3. Requirements for assessment of drainage damage and alternatives to direct storm water runoff control, such as utilization of recharge basins or other storage schemes.

4. Discussion of political, economic, legal and social problems related to urban water management.

The Center for Water ResourcesResearch of the Nevada Desert Research Institute has made substantial progress (C-1337) in developing basic criteria for effective management of a ground and surface-water supply system in an arid urban environment where water supply is limited and population is rapidly expanding. The study area is Las Vegas Valley of southern Nevada, one of the fastest growing urban areas in the United States, which has a large but heavily over-developed groundwater resource and is in process of working out a costly construction program for obtaining surface water from Lake Mead.

This research, which combines multi-disciplinary efforts of experts in fields of law, economics and engineering, has attracted widespread interest and cooperation. It offers excellent prospects for: (1) Value determinations of water in use; (2) understanding various legal alternatives in water resource management; and, (3) evaluating and explaining critical mathematical techniques for optimal integration of available water resources under alternative economic and legal structures. Progress is being made toward answering the question of how a new and fast-growing urban oriented population organizes for optimal water management and distribution. Such a solution is critical in this area as well as in other regions of the Nation where mounting population pressures are creating new demands for water.

At the University of Florida a study (C-1082) is nearing completion on applied criteria for municipal water-rate structures. It will include a comprehensive treatment of municipal water systems in the U. S.--number, type, ownership, descriptions of facilities, extent and kind of State regulation, structure and administration of publicly-owned systems, practices and policies, water use patterns, water pricing theory, and finally, applied criteria for water rate structures. Cost data of a well-regulated utility are analyzed to demonstrate effects of different rate basis on rate structures. Water utility executives and policy-making officials should find this report valuable for use in examining and evaluating their own policies and practices.

A study (C-1142) in Michigan is concerned with urban water policies and decision making in the Detroit metropolitan area. Tentative conclusions suggest political and institutional factors are more restrictive of development of a regional system, in an area fiercely protective of local autonomy, than are economic or social factors or projected business, industrial and residential demands.

Temple University reported, in project C-1388, that a regional approach to urban water system development might eliminate much apparent economic waste related to excess capacity. Present interconnections of urban water systems in the Philadelphia, Pennsylvania, area are economically feasible and represent a considerable potential for future interconnections.

Considering the likelihood that only limited additional water supplies can be imported into Arizona and other states of the Southwest, future development can be expected to depend upon efficient conservation and utilization of prevailing water resources. The problem of optimizing salvageable water resources has been under concentrated study for some time by Professor S. D. Resnick and his associates.

This research (A-011-ARIZ) began in fiscal year 1968 with an analysis of salvageable water resources in the semi-arid Tucson Basin. Factors involved included flood runoff, industrial and municipal wastewater, various treatment procedures, and the hydraulics of natural recharge from sandy ephemeral stream channels. This led to recognition, evaluation, and understanding of management alternatives for optimizing conservation, use and reuse of potential sources of water which previously have been wasted.

Promising results of the research encouraged the principal investigator to pursue the findings in detail with emphasis on urban and suburban areas. Project B-012-ARIZ will evaluate an experimental watershed that is now being encroached upon by urbanization. Potential is high for producing new and valuable findings on the entire problem of nature and management of water cycles in an area undergoing rapid urban development.

The purpose of Texas study C-1098 was to predict changes in runoff response of a small drainage basin due to increasing urban development in the basin. In particular the study was aimed at predicting future response and applying previously derived urban and rural equations to drainage basins in the Houston, Texas, area.

Data from seventeen watersheds in the Houston area and from thirty-three watersheds throughout the United States were analyzed. From this analysis, mathematical equations were obtained which predict the hydrograph for a drainage basin using easily measured physical features of the basin. These equations predict future hydrologic changes resulting from continuing urban development and provide a method for designing drainage systems which will not become inadequate due to future growth. Derived equations from the study were used to predict future changes in the hydrologic response of the seventeen Houston watersheds.

ABT Associates of Cambridge, Massachusetts have completed a study (C-1469) which involved research on ten case studies of urban water resources and related-land planning, based on interviews with urban planners, citizens' groups and engineering consultants, and on current planning documents. Water quality management, waterfront land use, water-related recreation and open space, and metropolitan growth were identified as critical problem areas in planning the interactions of urban activity and the water resource.

The planning of waterfront land use has been generally neglected by urban water resource planners. Planners have been extremely slow in responding to changing uses of such land, and have rarely taken advantage of its proximity to the water resource. Experience from the case studies suggested that marine-oriented commercial redevelopment of obsolescent urban waterfronts, and public control of remaining waterfront areas through acquisition, setback zoning, or sightline and use zoning, can help retrieve the urban waterfront for recreation and open space uses which take greatest advantage of its relationship to the water resource.

Planning of water-related recreation and open space has been left to the underfinanced, powerless jurisdiction of parks and recreation planners, while more powerful water resources officials have been reluctant to acknowledge their responsibility for recreational uses of urban water and related land resources. Recreational uses, however, are cited in justification of pollution control investments, and planners must thus ultimately examine costs and benefits of recreation. "Willingness-to-pay" benefit measurements and "need indices" were found to be potentially valuable tools for urban water resources planners. Effective use of such tools can help planners develop priorities and benefit-cost ratios that will in many instances justify opening of watersheds and reservoirs, now closed to the public for financial rather than public health reasons.

Metropolitan growth has posed serious problems of coordination and control in planning of service extensions, flood control and drainage, and water quality management. Though jurisdictional fragmentation, overlapping and competition will continue to constrain metropolitan water resources planning, urban planners can by their policy of service extensions and development controls exercise some control over growth patterns. The "limited access sewer line" and "blue-green" drainage planning are potentially valuable methods for controlling metropolitan growth and waterfront land use, but their success is largely dependent on their integration into broader regional plans. The research results are documented in the report, "Water and the Cities - Contemporary Urban Water Resource and Related Land Planning."

The Tri-State Transportation Commission in New York City notified OWRR that results of project C-1114, conducted by personnel of Barnard College of Columbia University, New York and reported on in the 1968 OWRR Annual Report, has immediate application to the long-range water supply and sewerage plan for the Tri-State Region (New York, New Jersey, and Connecticut).

The completed report indicated that beyond 1985 it appeared major subregional transfers would have to take place if the New York metropolitan Region is to satisfy its water needs from presently used sources plus untapped flows within the area. Exchanges between the New York City system and Long Island and/or northeastern New Jersey were among those contemplated. The alternative is to develop extra-regional sources or to turn to non-traditional methods, such as desalination. In any event a major shift away from the present managerial structure toward greater integration appears likely. As a means for expanding water resources the benefits from a unified approach to regional decision-making is impressive, either at the subregional level, as the simulation showed, or for the metropolitan area as a whole.

There are many multi-source, multi-sink water networks servicing urban regions in the United States. Findings and methodology developed in this program could have widespread application to these problems.

A companion study (C-1629) by Barnard College is entitled "Coordinated Management and Design of Metropolitan Area Water Supply and Waste Water Disposal Networks - a Linked Systems Analysis." The plan of research, using the New York Metropolitan Region as a case study area, is to consider: Behavior and design of the water supply system; collection of basic facts on wastewater disposal and sewage treatment facilities; a study of the operational efficiency of treatment facilities; relation between land use and type of effluent and treatment needs; definition of legal, administrative, and/or behavioral constraints on the total system that may influence selection of alternative paths to optimal solutions; design of a computer simulation model for a total water systems analysis, development of prediction and optimization models of future demands to be made on the total water system and design changes needed to accommodate the system to projected needs in order to optimize use of the resource; and, guidelines for establishment of a metropolitan area water authority for water supply and wastewater disposal systems.

Cornell University, Ithaca, New York has commenced work on a study (C-1640) entitled "Metropolitan Water Resources Systems Analysis." Investigations will be undertaken of application of systems methodology to preliminary planning, staging, design and operation of metropolitan water resources projects under hydrological, economic and political uncertainty. Mathematical planning models will be structured for defining and evaluating preliminary alternative designs and policies for municipal and regional water resources systems such as supply, distribution and treatment works, urban runoff collection, storage and treatment facilities.

Also, to be investigated are methods for predicting the effect of alternative pricing policies on design, capacity, and operation of water supply systems. Methods will be developed for use as tools by municipal planners to aid in establishment of rational prices or rates for various types of water use.

A study in Massachusetts (A-027-MASS) is directed towards development of methods for determining values, uses, and past and probable fates of minor water resources (ponds, wetlands, small streams) located in urban regions. The research is designed to test the hypotheses that (a) brooks and wetlands are disappearing from urban areas because their values are unknown and/or unappreciated, and (b) a city in humid regions without brooks and wetlands above ground constitutes an environment for human life inferior to one which has well cared for surface waters. Results of the research could lead to improved planning and utilization of water resources in urban areas.

Another project in Massachusetts (B-015-MASS) has as its purpose to develop a method to determine the interrelationship between changing functions of a river in an urban region and changing cultural values of the proximate inhabitants. It is hoped that this study will give resource and urban planners a means for understanding the cultural context of their work and a basis for planning resource use more rationally.

The Bureau of Business Research at West Virginia University completed a study on forecasting urban water demand (C-1212). Since water supplies systems are generally built to function for decades and area-wide systems of storage and distribution cannot be planned and constructed overnight, it is becoming increasingly important to project and plan for future metropolitan water needs.

This study should make a useful contribution to improving the methodology of forecasting. An analysis of factors associated with variation in water usage indicated that a general measure of area income and a general measure of overall area size are factors most closely associated with urban water usage. Five alternative projections of water demand for 141 standard metropolitan statistical areas were made, based on different assumptions relating to area size, income, and water rates. These projections should prove most useful to metropolitan planners and administrators responsible for assuring present and future water supplies.

Adapting the water resource planning process to problems and needs of metropolitan areas is the subject of research project C-1159 in North Carolina. The study developed a public investment planning and decision model which differs from the typical model used in U. S. river basin planning in four major ways: (1) System geographic boundaries take both the urban-metropolitan region and the river basin into account, thus incorporating water demand as well as water supply factors in the system; (2) scale of water-resource planning is much smaller than in conventional river basin planning, in that there is detailed analysis of small urbanized streams and watersheds in which land and water values are high; (3) the substantive content of water-resource planning emphasizes elements of special significance to urbanized areas--urban storm drainage, mass recreation, urban flood plain management and role of streams, canals, natural lakes and impoundments in urban spatial design; and, (4) water-resource planning is explicitly linked with other sectors of urban-metropolitan planning, including land-use, transportation, open space, recreation, public services and environmental quality aspects such as air quality and solid wastes management.

Preliminary findings have been used by the principal investigator in workshop sessions of Corps of Engineers' planners at Pennsylvania State in June and September of 1969, to suggest ways in which Corps of Engineers' planning can contribute more effectively to solution of urban-metropolitan water-resource problems. Continuation of the research will apply the model to four metropolitan areas in the eastern United States.

Research at George Washington University (C-1357) will investigate past behavior of water agencies in metropolitan Washington, D. C., assess performance, and recommend improvements. Initial appraisals suggest that agency actions are selected from a very narrow range of alternatives, and that formal and informal constraints pattern water services in distinct ways. Pricing structures are a complex blend of use-rates, fees, charges, etc. Average cost pricing rather than marginal cost pricing is entrenched. Retirement and service of debt play a dominant role in pricing decisions.

It is believed results of the project will be generally applicable to metropolitan areas by providing: (1) an overview of the allocation of water resources in metropolitan areas; (2) greater insight into the nature of institutions and the ways in which institutions, particularly the planning institutions, structure the allocation of water resources; and, (3) sensitivity for the role of information and information development activities in decision-making. Results are expected to increase understanding of institutions, decision-making, and planning which should enable metropolitan jurisdictions to make decisions affecting allocation of water resources with improved awareness of the economic consequences of such decisions.

An investigation has been completed in Alaska (B-006-ALAS) to determine the feasibility of using warm, summer streamflow to recharge groundwater aquifers in the Anchorage area and to restrict use of cold, winter water for recharge. The purpose is to provide a means of raising the temperature of the Anchorage municipal water supply to combat annual freezing problems that plague the municipal water distribution and sewer systems. This investigation shows that groundwater temperature can be raised by artificially sealing the recharging stream beds thus reducing recharge of the aquifers by cold winter water and by using warm, summer streamflow for recharge through artificially constructed recharge areas or wells.

Several Georgia projects have responded to widespread interest in urban water resources. Six hundred copies of a report on the relationship between metropolitan planning and river basin planning (B-009-GA) have been distributed and a second printing is under consideration. Most metropolitan areas were found to be handicapped because no one metropolitan government is authorized to represent the area for negotiation with river basin interests; and usually there is no river basin management agency with whom metropolitan representatives could negotiate. Significant changes that could be made in local, State, and Federal Water planning procedures are suggested which would give more and better control to metropolitan areas over development and use of their water resources.

Project B-011-GA has developed information for estimating domestic water demands as a function of price structure and consumer income. Two other studies (B-024 and B-045-GA) will provide improved measures for public opinion and perception regarding urban water management issues, and, project B-038-GA will seek to define the nature and scope of a program of metropolitan water resources management, examine institutional and financial arrangements, and develop guidelines for improved resources management.

A multidisciplinary investigation involving several annual allotment and matching grant projects (A-001 and 004-LA and B-001 002, 003, 004, and 005-LA) has produced results which show that encroachment of salt water in aquifers underlying Baton Rouge, Louisiana, can be stopped by construction and operation of two strategically placed scavenger wells to pump saline water to waste. The study demonstrated, also, that the Baton Rouge fault prevents the bulk of saline water in aquifers south of Baton Rouge from moving to the industrial area. One implication of the study is that net offtake of water from the aquifers must be reduced if land surface movement such as occurred in Houston, Texas, is to be prevented in the Baton Rouge area. The hydrologic, hydrogeologic, engineering, economic and legal aspects of this study are being summarized in one comprehensive report.

Project A-020-LA deals with subsidence of land surface in the Baton Rouge, Louisiana, area in relation to groundwater offtake. It is anticipated that the findings will be of considerable value to citizens of Baton Rouge in helping to determine the pace at which importation of additional water to the area should occur. Project B-004-LA relates to this problem, also, and points out that the Amite River would appear to be the most suitable source of water for importation from the standpoints of quantity and quality.

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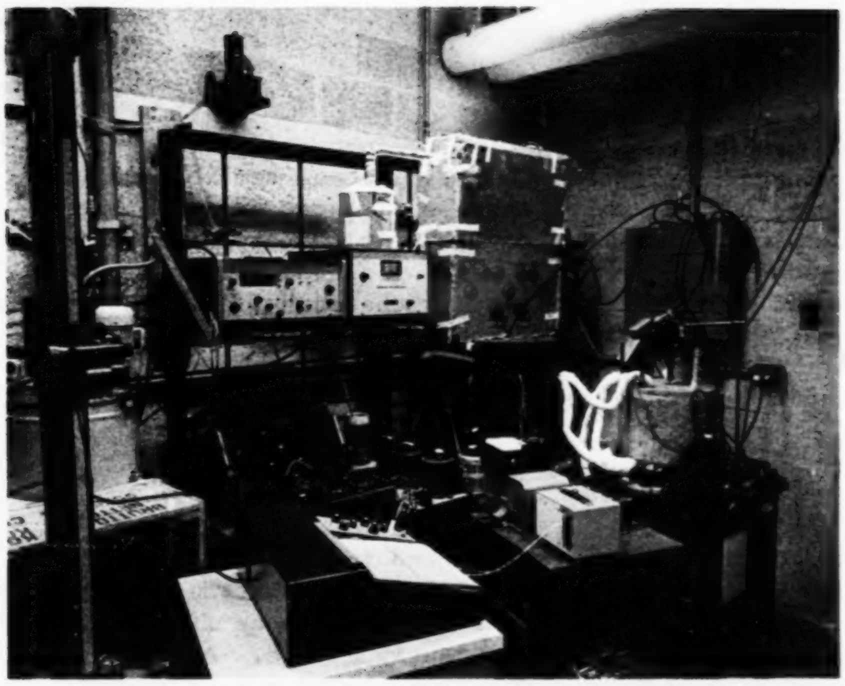
Much of the Laboratory Equipment is of a Sophisticated Nature; some must be handmade.

Mr.Chao Chia-Chen is inserting a final clarifier effluent sample in the turbidimeter to measure turbidity before treatment of the wastewater with a ferric chloride coagulant. (Based on Project No. A-012-SC).

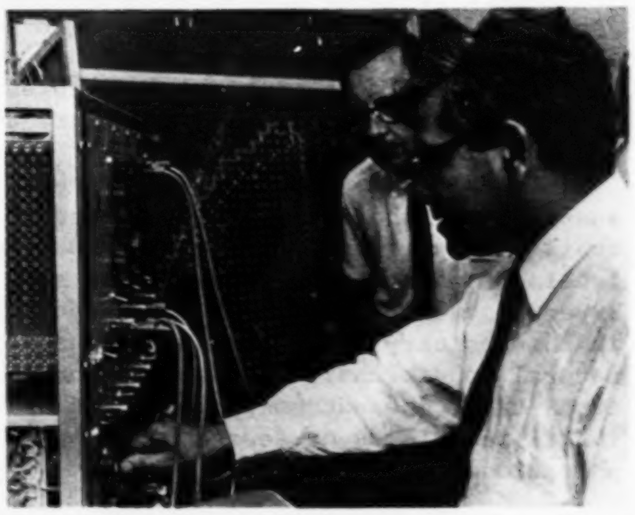
Photo, courtesy of Clemson University

Preparing a model for Project A-011-LA dealing with effect of formation dip on movement of fresh water stored in saline aquifers. A 6-inch layer of blasting sand in bottom of an 8-foot plastic pool simulates overburden pressure. Model can be tilted by hydraulic jacks under supporting platform. The principal investigator, Dr. Oscar K. Kimbler, is at the right.

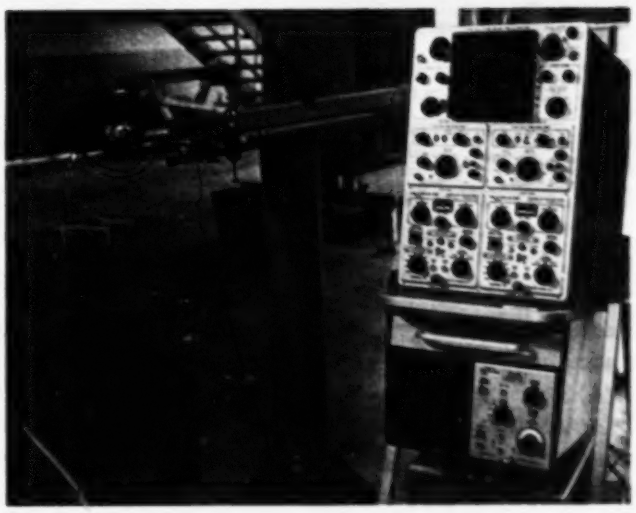


Equipment used in measuring vapor pressure isotope effects in aqueous systems. Photo courtesy Tennessee Water Resources Research Center

Analog model for ground water management in North Carolina demonstrated for Institute Director Howells by Principal Investigator Dr. Jabbar Sherwani, University of North Carolina at Chapel Hill. (B-005-NC)



Solenoid valve and associated instrumentation for water hammer measurements in friction reducing solutions. (Based on Proiect No. A-009-SC). Photo, Courtesy of Clemson University



Conservation of the Estuarial Water Resource

Statement of the Problem

The estuarial water resource is being subjected to increasingly intensive use. Urban land expansion, mineral exploitation, recreational development, commercial fishing, industrial use, deposition of waste effluents, and problems of siltation are increasingly complex forces that are shaping the estuarial environment and its future utility and value. An understanding of the simultaneous multiple processes currently and foreseeably affecting the estuarial zone and its contiguous land areas is essential to an intelligent program for estuary management. Research is needed in these many areas and on legal and institutional changes necessary for planning and initiation of an effective estuary program.

Research

Pamlico River Estuary in North Carolina is expected to be markedly changed as a result of phosphate mining and related industrial and population growth. The quality of estuarine waters is important because of their value as fishery nursery areas, for commercial and sports fisheries, and recreational use. A major research effort has been directed toward this problem since 1966 (B-004 and A-030-NC).

Start of an extensive phosphate mining and processing industry along the Pamlico River in 1965, created a need for measurement and prediction of possible eutrophication. The basic technique used was transect sampling whereby areas of the estuary with high and low concentrations of phosphate could be compared using measurements of water chemistry and biology.

As expected, there was an increase in the amount of phosphate dissolved or suspended in the lower river. However, in spite of increased amounts of phosphate available, algal photosynthesis and biomass did not respond and areas with low levels of phosphate gave about the same response as areas with high phosphate. Experiments with carbon-14 and added nutrients revealed that nitrogen was limiting in this estuary and that there appeared to be an excess of phosphate even under natural conditions. With one of the two important nutrients present in excess, it is therefore extremely important to keep nitrogen input to the estuary, from fertilized fields or sewage, at a low level in order to prevent future eutrophication.

An investigation is underway in Alaska (B-014-ALAS) to determine effects of spent salmon carcass decomposition on the organic and nutrient chemistry of a fresh water stream, in which decomposition commences, and in the estuary, in which the stream flows. Because decomposing carcasses of salmon that die natural deaths following migration to spawning areas are not dissimilar from industrial wastes discharged by salmon canneries, results of this investigation are expected to provide guidelines for maintaining control of pollutional effects of the salmon canning industry in Alaska and possibly other states such as Washington and Oregon.

Investigations of three major estuarine systems of the Chesapeake Bay complex-the York, Rappahannock and James Rivers--from the standpoint of source, pathway and effects of nutrients, mainly nitrogen and phosphorus, are being conducted in Virginia (B-003-VA). All three systems are enriched with nutrients from municipal and agricultural sources. Fresh-water systems usually respond to this kind of enrichment with increased phytoplankton productivity (eutrophication). However, the James and Rappahannock Rivers do not respond in this manner, but the York River does. How nutrients move in the former two is an elusive question now being pursued because of its obvious value in controlling the unwanted nuisance of eutrophication. In addition, correlations will be made with finfish and oyster production.

Project A-028-MASS in Massachusetts is concerned with development of basic information necessary for prudent management of an urban estuary. Data on physical, biological, and chemical parameters will be obtained. A materials balance will be developed for such items as nitrogen, phosphorus, coliform bacteria and pesticides in the estuary. This information will be used to evaluate impact of a proposed flood control project which will affect the estuary and, also, the effect of refuse disposal operations adjacent to the estuary.

Estuaries are complex, dynamic environments characterized by fragile ecosystems. Increasing pollution and man-made changes threaten their ability to serve man's many uses. An understanding of physical and biological processes of estuaries is essential to an intelligent program of estuarine management. Projects C-1214 and C-1428 involving utilization of physical and mathematical models in marine water resources have been supported with "seed" funds by OWRR to help develop a capability at Virginia Institute of Marine Science for physical and mathematical modeling of estuaries. Hopefully, this capability will be ready for application when the Corps of Engineers initiates the Chesapeake Bay Study with a hydraulic model of Chesapeake Bay.

Results to date include:

1. Training of a competent team of fluid dynamicists and oceanographers capable of working with mathematical and hydraulic models.

2. Contributing to critical evaluation and improvement of existing estuarine hydraulic scale model systems.

3. Utilizing scale models in development and evaluation of mathematical models of fresh water portions and estuarine portions of a classical, tidal tributary.

4. Improving existing mathematical models of estuarine systems.

5. Developing instrumentation for non-destructive sampling in hydraulic model systems.

6. Applying these techniques to real estuarine resource problems.

In Florida, efforts are being made (A-007-FLA) to develop methods to predict residence time of water in the State's estuaries and bays with a view to protecting quality of these environments from pollution. Mathematical models are being verified with empirical data from Lake Worth and Sarasota Bay. Emphasis in the future will be given to effects of wind and river inflow.

A Georgia study (B-035-GA) concerns estuarine hydrography and its role in transport of food and pollutants. It has been found that water circulation parallels the shoreline but reverses with seasons. Salinity and temperature contours are also parallel to shore. Decomposing organic materials exported from the marshes are confined to a narrow zone parallel to the coast, ten miles wide. Measuring and understanding these conditions are vital to protection of the ecology of the coastal zone, especially from the standpoint of maintaining spawning and nursery areas for economically important fishes and other organisms.

Dissemination and Application of Knowledge

Statement of the Problem

In recent years there has been greatly increased attention to water resources activities that are new in their technical aspects and professional involvements. Examples of water resource activities that involve physical, life, and social scientists and engineers are: water resources planning; water quality management; pollution abatement; water resource management in metropolitan environments; management and protection of estuarine areas, lakes, and marshlands; and management of heat rejected by thermoelectric generating plants. Properly informed consideration of, and action on, such matters requires ready access to results of research.

Information needs outstrip the capability of existing channels of communication. Response to these enlarged needs is limited by inadequate funds for technical information services and inadequacies of information dissemination technology. Diverse concern with improvement of information dissemination requires that attention should be directed to idenfitying:

(a) who should be responsible for such information dissemination; and

(b) what means of dissemination should be utilized.

Activities

Activity under this problem area has not involved actual research projects as much as it has action programs in the dissemination and application of knowledge. These action programs have fallen into various categories and are covered in Parts III and IV of the Annual Report under the following headings:

Part III

Water Resources Scientific Information Center program

Technology Transfer

Office of Water Resources Research Seminars and Meetings

Part IV

Water Resources Research Institutes and Centers activities in seminars, extension programs, and short courses as indicated in Directors' Statements.

Other Problems Related to the Hydrologic Cycle

Statement of the Problem

Research under this section deals with a broad array of basic studies of the natural occurrence, character, transport and distribution of water that are not specifically oriented to the other problem areas. Results from these studies often serve as essential supporting information to applied problems in water resources development and use.

Research

Industrial or economic development of some low-lying areas such as the Gulf Coast of Louisiana may be impeded by lack of a year-round potable water supply. In these areas, surface waters become brackish or salty in the low-flow period of streams and underlying water-bearing formations contain brine instead of potable water.

Projects A-002 and 011-LA involving development of a model for digital computer simulation of storage of fresh water in an aquifer containing brine, have elicited much local and national interest. Results have been sufficiently promising that the town of Empire in Plaquemines Parish, south of New Orleans, has, with assistance of consultants, constructed a prototype injection well 1000 feet deep and observation wells at the same depth to evaluate the efficiency of fresh-water injection of the aquifer and subsequent offtake of potable water. By June 30, 1969, some 30 million gallons had been injected in the test well and the fresh-water front was reported to have replaced salty water for a distance of at least 300 feet from the injection well. Continued research will study the effect of formation dip on movement of fresh water stored in saline aquifers and the efficiency with which it can be withdrawn.

A multi-county region in North Carolina encompassing estuaries of the Neuse and Pamlico Rivers is currently experiencing difficulties with groundwater supply of the Coastal Region because of dewatering operations associated with open-pit phosphate mining. Reduced pressures in the artesian aquifer threaten salt water intrusion, and the region has been declared a "capacity use area" with state regulation of water use. The Institute has undertaken research leading to development of an electric analog model to guide water management (A-026 and B-005-NC).

The prosecution of promising research in Hawaii under projects B-005, 008, and 011-HI in the significant field of groundwater problems has aroused strong local interest in the Water Resources Research Center's program at the University of Hawaii. Research by the Director and his associates in geophysical exploration for ground water sources, has received more than half of its support from non-Federal funding. As a result, effort under project B-015-HI is concentrating on a particularly hopeful line of endeavor concerned with remote sensing of water with electromagnetic radiation. This procedure is intended to exploit energy in the electromagnetic spectrum as a tool for exploration of geological structures controlling movement of ground water. Successful findings could have far-reaching application, in Hawaii, on other Pacific Islands, and on the mainland.

Research in Florida (A-011-FLA) is utilizing uranium and hydrogen radionuclides as natural tracers in the Floridan Aquifer. Results indicate uranium isotopes show a close relationship to hydrologic factors such as permeability and recharge and can also be used to test mixing models of aquifer water in a quantitative way. Also, the study has developed a highly successful method of analysis of tritium content in water without requiring enrichment of the samples. This technique represents a major advance over methods formerly available both as regards to expense and time.

Vermont project A-012-VT is the first part of a four part study to develop a model to describe the hydrology of Lake Champlain basin. The primary objective of this phase will be to develop a basic understanding of fluctuations in water levels in Lake Champlain. Specifically, records of the lake levels at Burlington, Vermont, and Rouses Point, New York, will be studied in an effort to delineate such characteristics as trends, cycles, periodicity, carryover and random components. This study of lake levels and development of a descriptive model will increase basic knowledge of how lakes behave and will be a contribution to future investigations and planning in Lake Champlain basin.

Continued success of irrigated agriculture in the high plains of eastern Colorado is dependent upon recharge of ground water in the Ogallala Aquifer. Project B-013-COLO is studying how ground water recharge is affected by surface vegetation and management. Initial results showed a significant increase in soil water accumulation was obtained where gravel mulch had been applied to field plots and vegetation was controlled by herbicides. This appears to be the only surface treatment in the study for which an appreciable fraction of the annual precipitation can be permanently stored in the soil profile. Surface runoff collection areas, such as Playa lakes and terrace basins, and irrigated fields were the only surface conditions where increased percolation could be predicted to contribute to ground water recharge.

It is hoped results will provide a practical means of substantially increasing the recharge rate, using land having limited economic value for other uses. Community and possibly legislative action will then be necessary to develop recharge facilities on a scale to make an effective impact on agriculture.

In terms of number of people and industrial plants served and quantity and quality of water available, the Atlantic Coastal Plain Aquifer is among the world's most important artesian aquifers. A Georgia study (A-006-GA) seeks a detailed understanding of its physical character for constructive conservation of this resource.

Results were applied to a practical public problem of mineral leasing and water supply in the Savannah, Georgia, area. A committee was appointed to evaluate the feasibility and effect of phosphate mining in the coastal area near Savannah. Priority was given by the Committee to the effect of mining operations on the Coastal Plain aquifer because of possibility of breaching overlying impermeable clays confining the aquifer. On the basis of information obtained in this research project, the hydrology of the aquifer indicates any breach of overlying impermeable clays would allow salt water to enter the aquifer and pollute Savannah wells. Had it not been for this research project, this information would not have been available.

Pennsylvania is conducting a broad investigation (A-005-PA) of carbonate hydrogeologic environments and their relationship to land use, and water resources development and management. Although this project has several more years to run, it has produced interim results of considerable practical value in alleviating or preventing frost heave and other failures of structures, flooded basements, lagoon and septic tank failures, and ground water and surface water pollution.

Wisconsin project B-009-WIS is involved in investigations of circulation of Lake Superior. Infrared temperature survey flights have been used to determine surface temperature data for spring, summer, and fall. Direct measures of current and thermal structure of the lake between Keweenah Peninsula and Isle Royale have been made. Three approaches using field, laboratory model, and theoretical studies have been used in the evaluation.

A significant result of the study has shown that strong and relatively narrow (1-10 miles wide), counterclockwise boundary currents occur along the perimeter of the lake. These boundary currents have important consequences regarding waste disposal and pollution in the lake. It is anticipated that results will be useful in improved water resources management of Lake Superior and the Great Lakes in general.

Project B-002-IND completed studies in Indiana in which effects of urbanization on time lag, magnitude of peak discharge, time to peak discharge, and frequency of peak discharge were quantitatively deduced. Because rainfall and runoff data for both urban and pre-urban conditions of watersheds are commonly unavailable, analysis was made of data from watersheds in the same region though in different stages of urbanization. Such analysis reveals effects of urbanization on runoff characteristics.

Another Indiana study (A-007-IND) is concerned with constructing a quantitative system of stream classification. Under test is a computer program which produces contoured slope maps from elevation data. If successful, it will be combined with stream order and terrain analysis programs to produce a computer package. This in turn, would provide all geomorphic parameters for a drainage basin study from a set of gridded elevation points.

Completed study B-005-ILL developed a mathematical model to relate hydraulic parameters, i.e., discharge velocity, width, depth, and cross-sectional area, to drainage area and flow frequency of the stream. Comparison between the mathematical model and observed data in Illinois and Indiana was good.

Illinois project B-023-ILL will expand this research nation-wide to include ten additional streams chosen to represent a wide variety of physiographic and hydraulic conditions. Results are expected to make an important contribution to the understanding of all river systems, and will aid in planning projects for control or development of rivers anywhere.

The role of Langmuir circulations in the mixing of Lake George, New York, is being studied in project B-015-NY. The principal investigator reports that support from OWRR has encouraged the Atmospheric Sciences Research Center and the Department of Atmospheric Science at the State University of New York at Albany to participate in the work of an Institute of History, Art and Science with respect to limnology, ecology and studies of the air-water interface. He reports further that the research program has brought about renewed interest in the phenomenon of Langmuir circulation on an international scale.

The project has yielded detailed measurements of both atmospheric and aquatic conditions before and during occurrence of Langmuir circulations showing circulations are a major cause of epilimnion mixing and thermocline formation and movement. As such, they have a substantial effect on evaporation rates and diffusion rates. A practical aspect of this research has been development of improved instrumentation for determining air and water temperature, wind speed and direction, relative humidity, and capillary wave heights.

Research on Other Problems Including Engineering Structures and Data Collection

Statement of the Problem

This subject covers a number of problem areas including: research designed primarily to improve the strategy for establishing field data collection programs, data acquisition methods, and data evaluation, processing and publication programs; research having a prime objective of development of new technology for designing, constructing, and operating water resources engineering works; and other research not specifically included in the problem areas.

Research

The principal objective of project C-1414 being conducted by Surveys and Research Corporation of Washington, D. C., is to develop and test a methodology for obtaining, via a mail survey, measures of manpower supply and demand in the field of water resources. As a basis for design and coverage of the mail survey, the contractor undertook a classification of water resources activities, as well as a listing of major types of employing organizations, with rough estimates of the number of establishments in each type.

The mail survey was launched in April 1969, and 200 questionnaires were sent to respondents selected to be illustrative of principal types of employment settings in which trained water resources personnel may be found. Information was requested on position or occupational titles in use, level of responsibility and principal function, educational and other requirements for appointment, number of incumbents by principal field of training or experience and full or part-time status on water-related activities, budgeted vacant positions by principal reason for vacancy, estimated changes in manpower requirements 1969-79, and current provisions for training and educational leave.

Concurrently, similar data were assembled, via interview and correspondence, on water-related positions in the Federal Government, which was excluded from the mail survey.

Examination of early returns indicates there has been excellent cooperation by respondents, that questionnaires have been completed conscientiously and that information provided is excellent and meets objectives of the project.

Dr. James E. Lewis is undertaking a study of manpower requirements in the field of water resources research in project A-015-LA. This Louisiana study compares available statistical data on potential supply of highly trained manpower with published estimates of demands. Dr. Lewis does not consider outlook for manpower in this area to be bright because of limited supply of people with requisite interests and abilities to do the research and the large demand on the part of technical and professional fields for precisely this type of personnel.

Indiana, recognizing importance of reliable information on the State's water resources research, manpower, and training needs, completed a detailed study (A-008-IND) in this critical field. It was found an already serious and growing problem exists in the State of Indiana (as well as in the Nation) due to shortage of qualified professional and technical personnel in fields of pollution and environmental control and water resources. The study pointed out large and growing career opportunities in these fields, and in related research, and indicated methods of counseling and encouraging students to enter these occupations.

The comprehensive study resulted in eleven recommendations, one of which was for Purdue to offer a two-year associate degree program in pollution control technology.

Arkansas project A-008-ARK is involved in developing digital systems for on-site data collections for water quality analysis. The study enumerated five requirements for a remote monitoring station. A system was designed and developed from commercially available components which met specified requirements. The unit can be contacted from a central station by telephone or teletype for playback of the day's recordings.

A system for coding and machine processing of ground water data has been developed in Montana (A-014-MONT). Computer programs and forms for processing well, spring and water quality data have been written. The processing system provides a uniform integrated approach to data collection and processing with considerable saving in manpower. The system is easy to use, economical, and accurate.

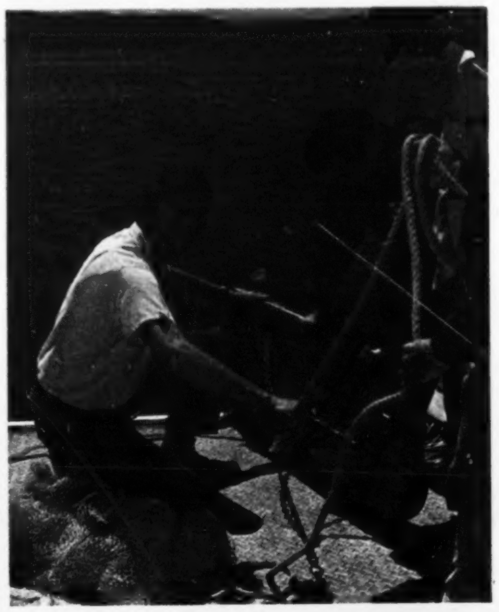
Massachusetts Institute of Technology is developing a generalized computer language for hydrologic and hydraulic analyses under project C-1495. A preliminary computer system has been developed which shows promise of application in all planning, design and operation situations where open channel water surface profile (both steady and time-varying) computations are required.

Project A-018-NC produced an extensive bibliography and date inventory of all published and some unpublished information on North Carolina water resources and completed a series of four studies providing background information necessary for water resources research planning and its integration with operation programs. The report will also be useful to consulting engineers, planners, regulatory agencies, citizen groups, and others who would like to know what information is available on the water resources of North Carolina and where it is located. It was prepared in recognition that few people have time to conduct state-wide searches for information in their fields of interest or concern.

Development of geochemical and geophysical techniques as an aid to determining availability of ground water in limestone terranes has received considerable impetus in Alabama (B-007-ALA). One of the outgrowths of the study has been preparation on computer cards of an annotated bibliography of more than 2000 references to the hydrology of limestone terranes. The bibliography is to be published as a part of the International Hydrologic Decade and should be very useful in facilitating research in this area.

Illinois has conducted a study (A-025-ILL) on identification and critical analysis of selected literature dealing with recreational aspects of water resources use, planning and development. Methods have been developed to identify, locate, manually retrieve, and classify literature on this subject. A computerized bibliographic retrieval process has been developed geared to key word inputs. A topical outline of knowledge dealing with the subject area has been constructed to provide a framework for critical analysis. Existing knowledge and gaps in information has been demonstrated which has led to development of an interdisciplinary recreation-water resources research program.

Investigations of the biological aspects of water problems extend from one-celled organisms to vertebrates as they affect, or are affected by water.

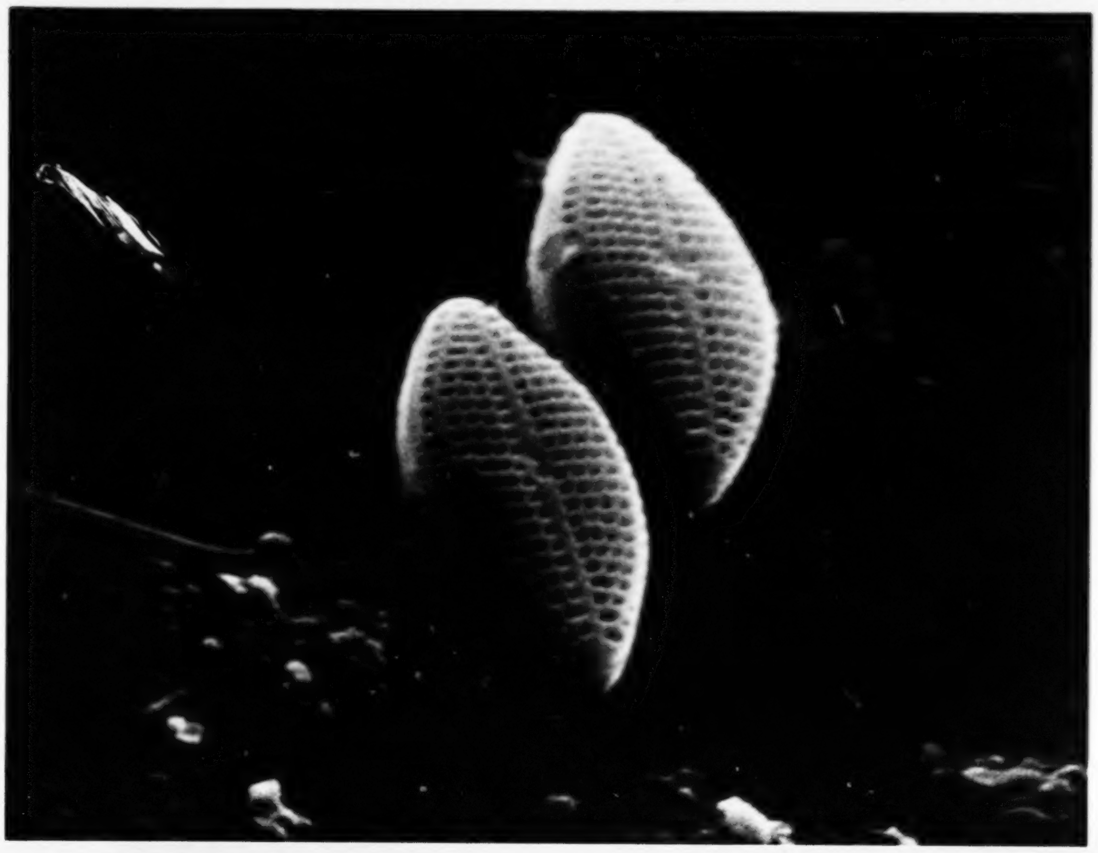


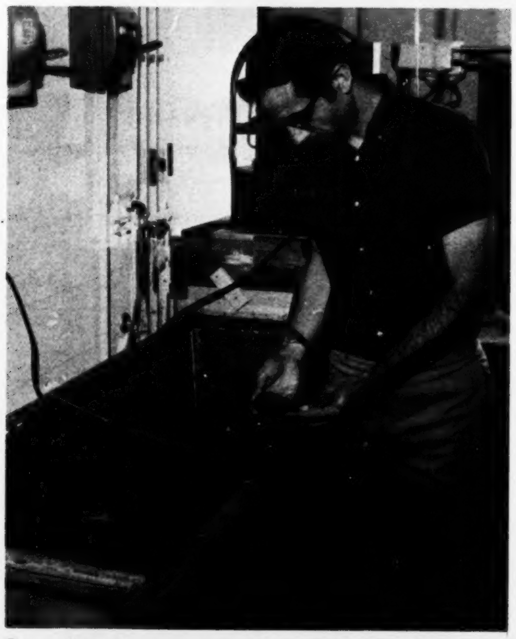
Planeing board used with bottom trawl for capture of fish in Bear Lake, Utah-Idaho
Photo, courtesy Utah Center for Water Resources Research

A benthic sample with a high organic content is being taken from a floodplain pool. Photo, courtesy Illinois State Natural History Survey

A mass of aquatic vegetation, primarily coontail or Ceratophyllum lifted on a pole through a mat of fallen tree leaves, duckweeds and other plants. The relation of floodplain pools such as this to the biological production of the Kaskaskia River, Illinois, is being studied in B-025-ILL.
Photo, courtesy Illinois Natural History Survey

Lake George, New York diatoms, Cocconeis pediculus as they appear under a scanning electron microscope at 6600 x magnification. Project C-1484





Freshwater mussels are being used in a procedure for monitoring natural waters for pesticide content. The picture shows James W. Bedford, a graduate research assistant inspecting a mussel that is being kept in a laboratory holding tank. Photo, courtesy Michigan Institute of Water Research

Project A-027-MICH is attempting to find an organism that may be better than Escherichia coli as an indicator of domestic sewage pollution. The photo shows collection of mid-stream water sample using an aseptic technique developed for analysis of the little known prosthecate bacteria. Photo, courtesy Dr. James T. Staley, Michigan State University

PART II

MANPOWER, TRAINING AND PUBLIC INVOLVEMENTS

MANPOWER AND TRAINING ASPECTS OF THE COOPERATIVE WATER RESOURCES RESEARCH AND TRAINING PROGRAM ARE DISCUSSED, AS ARE SOME OF THE REGIONAL ACTIVITIES OF THE STATE INSTITUTES, AND PUBLICATIONS AND REPORTS EMANATING FROM THE PROGRAM. THE SCIENTIFIC DISCIPLINES OF 1194 PROFESSIONAL INVESTIGATORS AND 1862 STUDENT RESEARCH ASSISTANTS IN TITLE I PROJECTS ARE COMPARED WITH 215 PROFESSIONALS AND 114 STUDENT ASSISTANTS ENGAGED IN TITLE II RESEARCH. ENGINEERS, PARTICULARLY ON TITLE II PROJECTS, WERE MOST NUMEROUS AMONG THE INVESTIGATORS. THE ENGINEERS WERE FOLLOWED IN NUMBER BY ECONOMISTS AND MATHEMATICIANS-STATISTICIANS-COMPUTER SPECIALISTS IN THE TITLE II PROJECTS, AND BY BIOLOGISTS, GEOLOGISTS AND ECONOMISTS IN THE TITLE I PROGRAM. EXAMPLES ARE CITED IN WHICH 71 PROFESSIONALS WHO PREVIOUSLY HAD NOT DONE WATER RESOURCES RESEARCH WERE ATTRACTED TO THE WATER FIELD, BRINGING WITH THEM NEEDED NEW COMPETENCE. PARTICIPATING UNIVERSITIES REPORTED THE DEVELOPMENT OF 286 NEW WATER-RELATED COURSES, AND EMPLOYMENT OF 238 STAFF MEMBERS FOR NEW POSITIONS AND 72 FOR REPLACEMENT LAST YEAR. APPROXIMATELY 13 PERCENT OF THE NEW EMPLOYEES WERE SUPPORTED, IN PART, BY P.L. 88-379 FUNDS. SEVENTY-SIX COLLEGES AND UNIVERSITIES PARTICIPATING IN THE PROGRAM REPORTED AN ENROLLMENT OF 3027 GRADUATE AND 24 POST-DOCTORAL STUDENTS IN WATER-RELATED FIELDS. THE STATUS OF 4978 GRADUATES DURING THE 1968-69 SCHOOL YEAR WAS REPORTED AS FOLLOWS: 33.7% UNKNOWN AND 7.4% UNEMPLOYED OR IN NON WATER-RELATED POSITIONS; OF THE REMAINING 59%, 47.4% OBTAINED WATER-RELATED POSITIONS, 28.9% RETURNED TO SCHOOL FOR FURTHER TRAINING, AND 23.6% WENT INTO MILITARY SERVICE. EXAMPLES OF PUBLIC INVOLVEMENTS OF STATE WATER RESOURCES INSTITUTIONS ARE GIVEN, INCLUDING ACTIVITIES OF REGIONAL ASSOCIATIONS. DURING THE YEAR 1968-69, THE TITLE I PROGRAM PRODUCED 574 PUBLICATIONS, 225 THESES AND DISSERTATIONS, AND 230 PROJECT COMPLETION REPORTS. THE TITLE II PROGRAM PRODUCED 52 PUBLICATIONS, 5 THESES, AND 13 PROJECT COMPLETION REPORTS. ELEVEN DOCUMENTS OR SERIAL PUBLICATIONS WERE PRODUCED BY OWRR-WRSIC AS AN ORGANIZATION AND 8 WATER-RELATED PAPERS WERE PUBLISHED BY OWRR STAFF MEMBERS.

Introduction

This part of the report deals with manpower for research and training, improved capabilities of the universities for research and training, student research assistants in the P.L. 88-379 program, numbers of water resources students and their status after graduation, publications and reports emanating from the program, and other activities of the State water resources research institutes.

Manpower Aspects

Title I Research Investigators

Nearly 1200 professional investigators from literally dozens of scientific and engineering disciplines were engaged in research on Title I projects during 1968-69. They were assisted by 1862 students also representing a wide variety of disciplines.

Professional Investigators (Title I)

The professional investigators of Title I projects have increased from 629 in Fiscal Year 1966 to 1194 in Fiscal Year 1969. They are shown by scientific discipline for each of the past four years in Table 1. Nearly four-fifths (78.9%) had doctoral degrees; 17.7 percent, masters' degrees; and 3.4 percent, bachelors' degrees. Percentages were similar in the previous three years.

By grouping more or less arbitrarily the ten or more types of engineering and the many specialized areas of biology and economics concerned with water into single or few categories, there are still 58 fields shown in Table 1 indicative of the pervasive nature of water resources research. Engineers are predominant among the disciplines represented, followed by various biological sciences, economics, geology, chemistry, physics, and soil science. The 422 engineers reported may be categorized or subdivided as follows: civil, 160; agricultural, 95; sanitary, 44; chemical, 38; hydraulics, 30; industrial, 13; mechanical, 11; environmental, 11; electrical, 11; nuclear, 5; and petroleum, 4.

It is of interest to note that, in 1969, anthropology was represented by 4 individuals, art by 1, computer science by 2, history by 1, political science by 16, psychology by 5, and mathematics by 5. In many projects there were several disciplines represented. Continued efforts are being made to foster multi or inter-disciplinary approaches to research on water problems. Examples of these are given in connection with the subsequent discussion on Title II research investigators.

A large interdisciplinary project requires team work. Here both faculty and students of the University of Wisconsin participate in a discussion on the progress of Title II Project, "Institutional Design for Water Quality Management: A case study of the Wisconsin River Basin." (C-1228)

Table 1

SCIENTIFIC DISCIPLINES OF PROFESSIONAL INVESTIGATORS OF TITLE I PROJECTS, 1966, 1967, 1968 and 1969

Discipline of Investigator	Number of Professionals FY 1966	FY 1967	FY 1968	FY 1969
Aerial Photo Interpret.			1	1
Agronomy	12	23	20	19
Anthropology		1	1	4
Architecture (Landscape)			1	5
Art				1
Atmospheric Science	1	1	3	
Behavioral Science			2	
Biology (Including Micro)	35	59	58	77
Botany	13	14	16	25
Business Admin.		1	2	2
Chemistry	26	29	56	55
Climatology	4	2	1	
Computer Science				2
Conservation	1	2	2	2
Earth Science		4	1	
Ecology	10	7	10	5
Economics	45	72	88	100
Education		1	1	2
Engineering	242	329	331	422
Environmental Science		1	7	10
Fish and Wildlife	17	21	22	23
Food Science	2	2		2
Forestry	13	12	12	20
Geography	9	14	13	13
Geology	72	74	67	93
Government		3	1	
History	1	1	2	1
Home economics			1	1
Horticulture	4	3	6	10
Hydrology	14	7	21	29
Industrial Relations		1	2	
Law	15	33	22	26
Limnology	4	11	18	23
Mathematics			3	5
Meteorology	10	9	8	14
Mineralogy	2	5	5	4
Natural Resources				1
Oceanography (Marine Sci.)	1	2	3	5
Pharmacology				3
Planning	2	2	3	6
Political Sci. and Public Admin.	5	10	12	16

Table 1 (Cont.)

Disciplines of Investigators	FY 1966	FY 1967	FY 1968	FY 1969
Psychology	2	1		5
Public Health		3	2	
Radiology	1			
Range Management				1
Recreation & Parks	2	6	2	4
Sanitary Science		1	1	1
Seismology	1			
Sociology	4	7	8	18
Soil Science	17	20	24	36
Statistics			1	3
Toxicology		2		
Vet. Science	1			1
Water Resources	3	11	4	
Watershed Management		2	2	
Zoology	24	27	50	53
Total	629	855	965	1194

Research sociologists at Utah State University, Dr. Wade H. Andrews, left, and Dennis C. Geertsen, right, are reviewing data tabulation analysis of attitudes toward the Bear River Basin development. Photo by Utah Center for Water Resources Research

Table 2

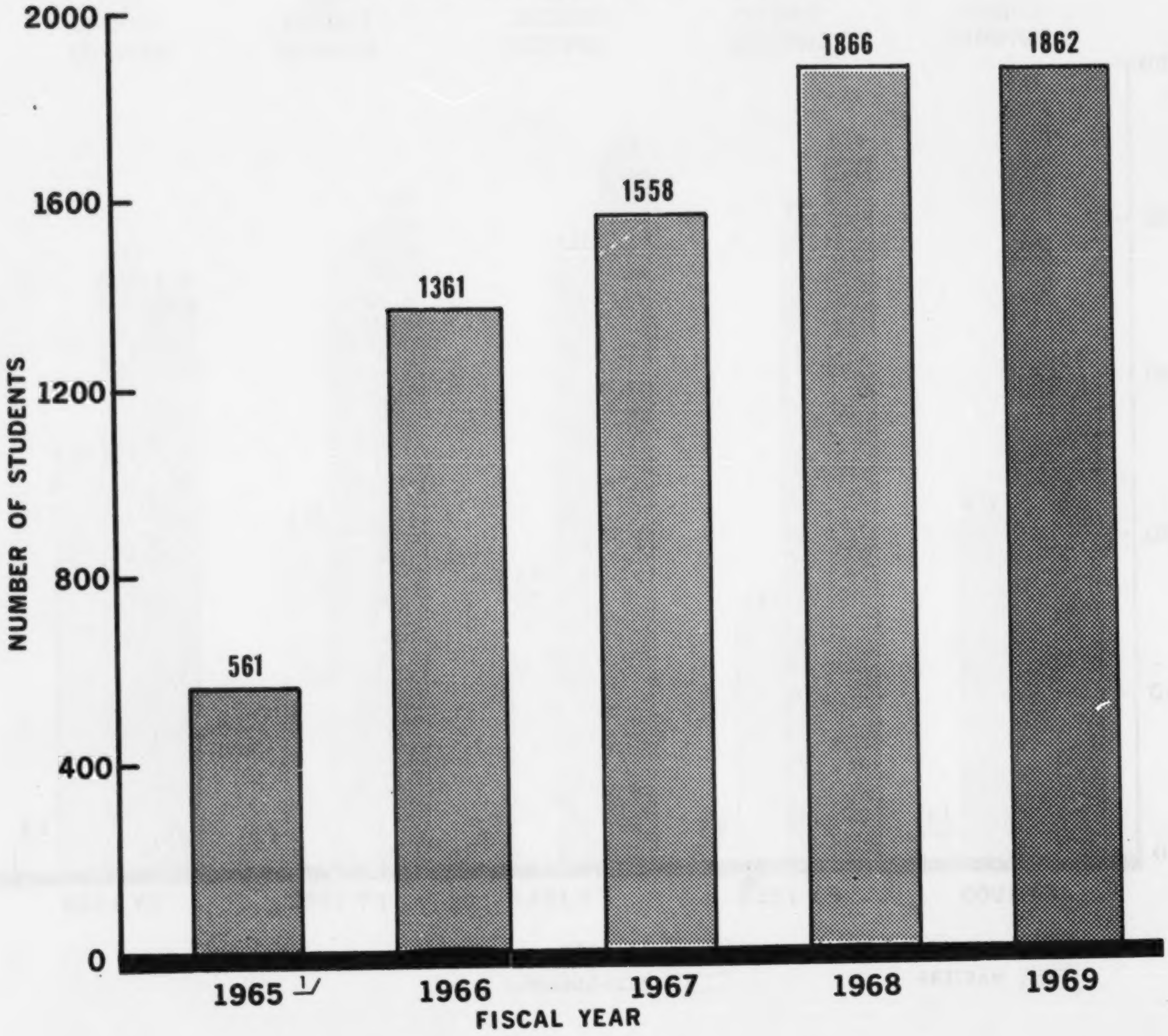
THE SCIENTIFIC DISCIPLINES AND EDUCATIONAL STATUS OF STUDENT RESEARCH ASSISTANTS WHO RECEIVED P.L. 88-379 FINANCIAL SUPPORT, FISCAL YEAR 1969

Scientific Background Area of Student	Educational Level of Students				
	Undergraduates	Master's Candidates	Doctoral Candidates	Post-Doctoral	Total Students
Agriculture	25	9	8		42
Agronomy	9	12	8		29
Anthropology	2	4	3		9
Architecture (Landscape)	4	5			9
Art	2				2
Atmospheric Science		1	1		2
Bacteriology	2	2	1		5
Biology	64	52	41		157
Botany	6	8	11	2	27
Business Admin.	7	11	2		20
Chemistry	23	24	18	4	69
Computer Science	1	5			6
Conservation		1			1
Earth Science	1	1			2
Ecology		5	4		9
Economics	31	39	32	1	103
Education	16	2			18
Engineering	244	254	146	7	651
Entomology	2	5	1		8
Fishery Biology	12	7	4		23
Food Technology	1				1
Forestry	16	16	6	1	39
Fuel Science	1				1
Geography	12	5			17
Geology	29	48	31		108
Government				3	3
History	2	1			3
Horticulture	2	4	4		10
Hydrology	9	12	11	2	34
Industrial Management		4			4
Information Science	1	1			2
Journalism	1	1			2

Scientific Background Area of Student	Educational Level of Students				
	Under-graduates	Master's Candidates	Doctoral Candidates	Post-Doctoral	Total Students
Law	9	8	2		19
Liberal Arts & Humanities	17				17
Library Science		2			2
Limnology		5	7		12
Marketing		1			1
Mathematics	4	5	1		10
Meteorology	6	1			7
Microbiology	15	24	10	3	52
Natural Science	1				1
Oceanography			1		1
Physics (Geo. & Soils)	18	13	11	3	45
Planning (City & Reg.)		7	1		8
Pharmacology			1		1
Physiology	1				1
Political Science	4	9	3		16
Pre-medicine	2	2			4
Public Health	7	4	5		16
Recreation & Parks		2	3		5
Resource Development	1		3	1	5
Science	2				2
Sociology	3	7	10		20
Soils	9	10	16	2	37
Statistics			1		1
Textiles & Clothing		1			1
Vet. Medicine	1		1		2
Water Resources		5	8		13
Watershed Management	9	2	6		17
Wildlife Biology	10	17	7		34
Zoology	23	34	33	4	94
Total: 61 disciplines	669	698	465	30	1862

FIGURE 3

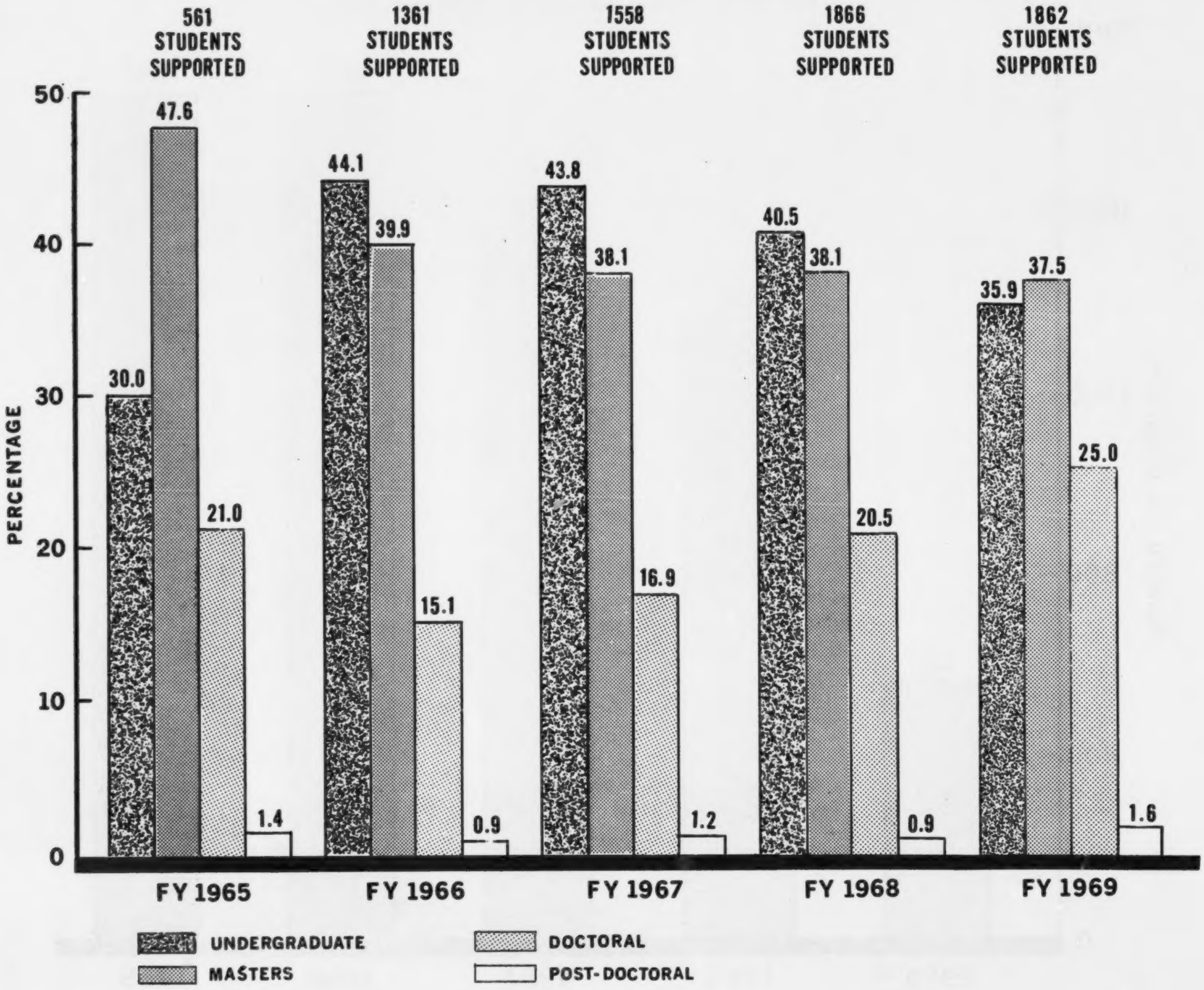
STUDENTS RECEIVING FINANCIAL SUPPORT BY SERVING AS RESEARCH ASSISTANTS IN THE P.L. 88-379 PROGRAM



1/ Funds were available in Fiscal Year 1965 for the latter part of the year only.

FIGURE 4

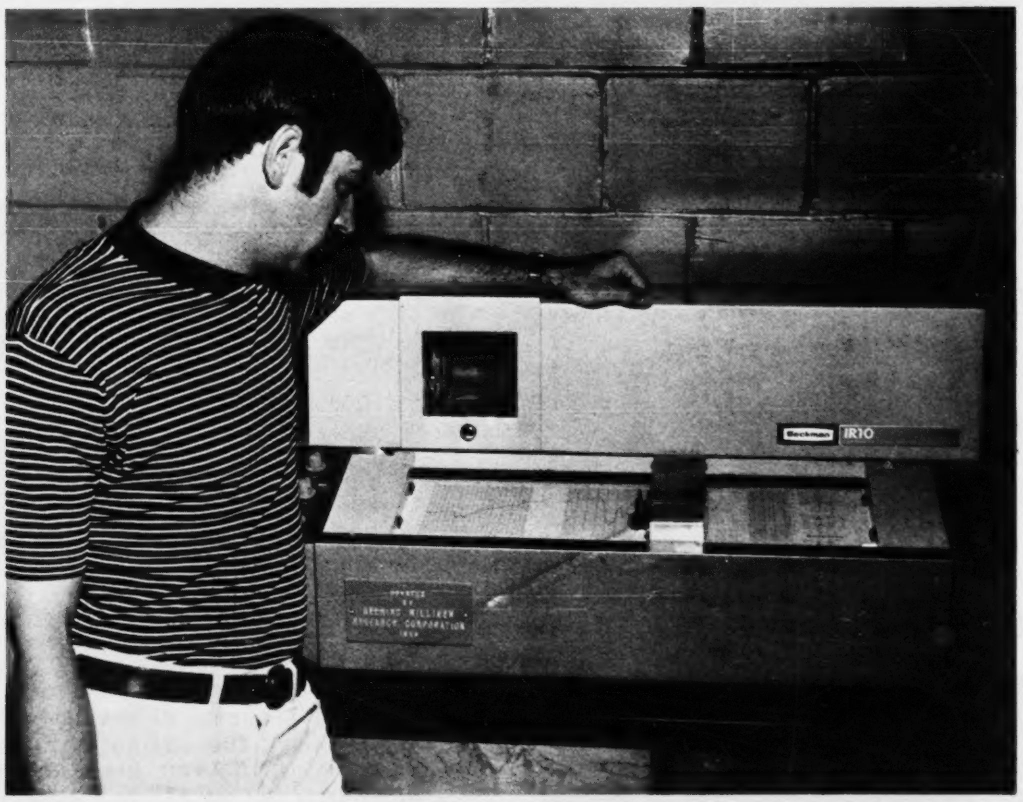
ACADEMIC LEVEL OF STUDENTS RECEIVING FINANCIAL SUPPORT BY SERVING AS RESEARCH ASSISTANTS IN THE P.L. 88-379



Student Research Assistants (Title I)

The level of funding for Title I research remained the same in Fiscal Year 1969 as it was in Fiscal Year 1968 and the number of students reported as having received P.L. 88-379 financial support as research assistants likewise remained essentially the same -- 1862 in 1969 as compared with 1866 in 1968. The numbers are shown graphically for the past five years in Figure 3 and, according to academic level of the student assistants, in Figure 4. There has been an increase in the percentage of assistants who are candidates for the doctoral degree -- 15.1 percent in 1966 to 16.9, 20.5, and 24.9 percent, respectively, in 1967, 1968 and 1969; whereas the percentage of undergraduates has declined from about 44 percent to 36 percent of the total.

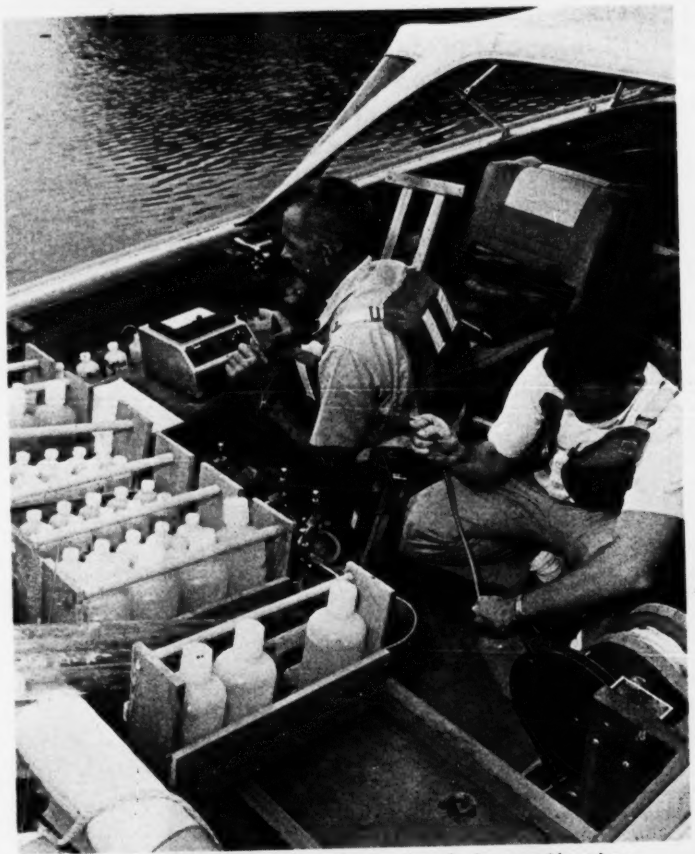
The scientific discipline and educational level of student assistants are shown in Table 2. By grouping some specialized types of engineering, biology, economics, and other disciplines into relatively broad categories, student assistants are listed in 61 disciplines. Engineering, with 651 students, constitutes the largest group -- 35.0 percent of the total -- followed by biology, considered broadly, with 413 students; geology, with 108; economics, with 105; and others, with lesser numbers. This is a pattern similar to that of last year; however, more students appear in these annual compilations with background training in such fields as anthropology, sociology, and landscape architecture than was true during the first year or two of the P.L. 88-379 program.



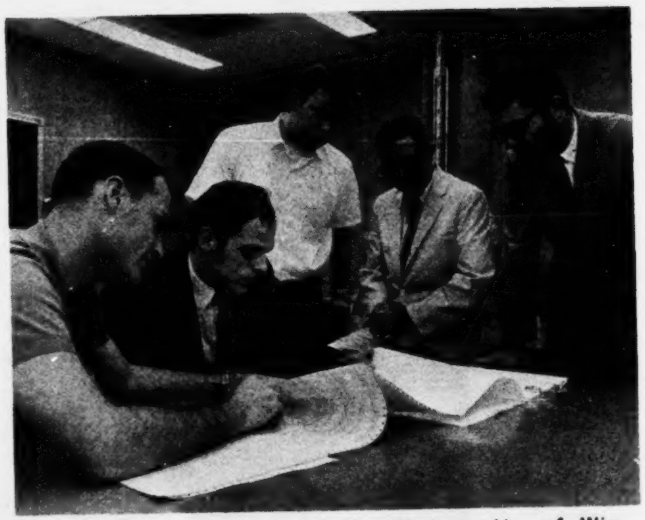
Graduate student Stancil D. Powell in the A. French Textile School, Georgia Institute of Technology, is identifying through spectrophotometric analysis the degradation products of biologically degraded dyes. (B-027-GA)

Students serving as research assistants to well qualified professional investigators gain valuable training and research experience. Nearly 2,000 students received financial support while working as assistants on PL 88-379 projects in 1969 and a much larger number benefitted from supplies and equipment purchased for approved projects.

Laboratory Technician Dorothy Waring precipitates warp size in research on textile wastes. Dr. Carl E. Bryan, Department of Textile Chemistry, North Carolina State University, is the principal investigator (A-035-NC)



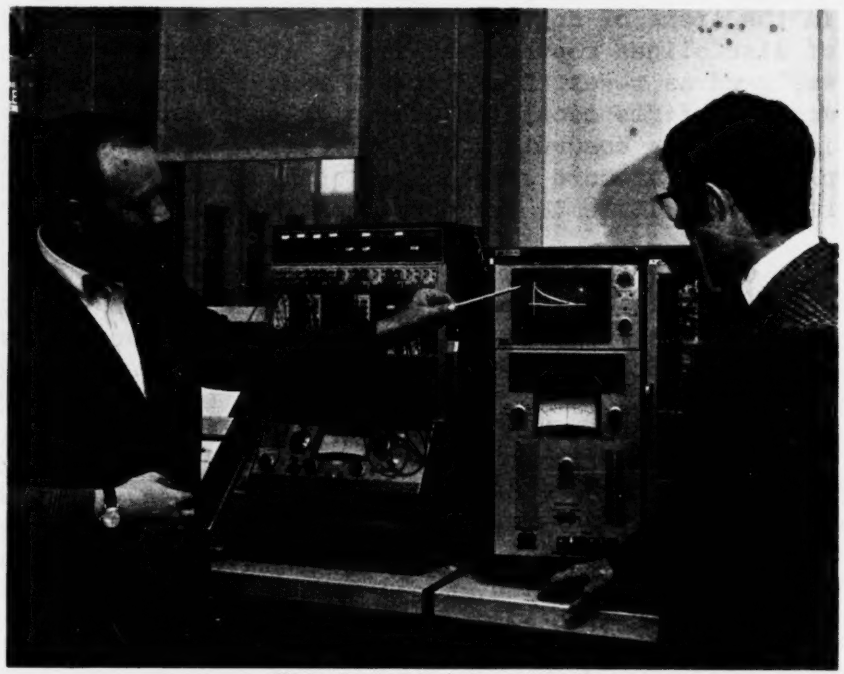
Dr. John M. Lawrence, Principal Investigator, and David Bayne, Graduate Research Assistant, of Auburn University sampling water in Lakes Eufala and Seminole to determine nutrient input-storage-output relationships. Project B-015-ALA.



Faculty and students of the University of Wisconsin examine the computer print-out sheets they are using in their preparation of a macro-water quality model for the Title II project, "Institutional Design for Water Quality Management: A Case Study of the Wisconsin River Basin." (C-1228) (l. to r.) Charles Mc Quillan, James Fritsch, Gerald Stadler, Charles Falkner and Alasdair Mac Cormick. Photo, courtesy University Extension, University of Wisconsin

Use of collecting equipment being explained to students. Bottom trawl in foreground. Photo, by Utah Center for Water Resources Research

Two graduate assistants retrieving a viral sampling pad from a wastewater treatment plant tank for laboratory examination in Project A-026-MICH.



Mr. Paul Schorr (right) and Dr. B. Davidson are shown at the analog computer during a simulation run on project B-011-NJ. The oscilloscope picture shows a set of simulated DO and BOD curves used in a particular aeration station design calculation. A change in the potentiometer settings causes the system parameters to change, thus resulting in a new design. A permanent record of the calculations are obtained on the X-Y plotter.

Photo, Courtesy New Jersey Water Resources Research Institute

WISCONSIN
RIVER
BASIN

Professor Irving K. Fox, Associate Director of the Water Resources Center at the University of Wisconsin and Chief Investigator of the Title II Project No. C-1228, points to the location of a paper mill on the map of the Wisconsin River Basin. The other members with Professor are studying aspects of financing and economic incentives of water quality management, the possible effects of water levels in reservoirs upon recreation values, and the results of a survey made on the attitudes of the public.

Title II Research Investigators

Activation of Title II of the Water Resources Research Act enhanced opportunities of bringing to bear on water problems research competencies of academic institutions as well as qualified individuals, public agencies and private and non-academic organizations not previously participating in the program.

Inasmuch as research priorities suggested for Title II research projects often involved systems analysis and focused, to a large extent, on planning methodologies, the percentages of research investigators have tended to be higher in the areas of engineering, economics, and mathematics than for the wider spread of disciplines represented among Title I project investigators. Also, students employed as research assistants were fewer in number, particularly for the non-academic firms receiving grants or contracts. A tally made of 32 academic institutions conducting Title II research projects showed that 31 of them employed one or more student assistants, whereas 19 of 25 non-academic organizations with Title II projects employed no students.

Of 215 professional investigators assigned to 57 Title II projects, 118 were engineers, 24 were economists, and 15 were mathematicians, statisticians or computer specialists. Assisting these professional investigators were 114 students, nearly 39 percent of whom had their master's degree and 41 percent their bachelor's degree. The level of formal, academic training for Title II professional investigators was lower than that of Title I investigators. Among the principal investigators of 23 Title II projects conducted by non-academic organizations, were 5 with the bachelor's degree, 11 with master's, and 7 with doctoral degrees. Seventeen of the 23 were engineers. These private research organizations, however, have a wealth of experience in space, defense and other types of investigations, and specialists in many areas who can apply their knowledge and techniques to complex water problems.

As an example, Booz, Allen and Hamilton, Inc., in project C-1370, is making an analysis of managerial, financial, and regulatory functions of regional water resources authorities and other institutional arrangements. Heading up this study is a doctor of engineering with a background in physics, mathematics and operations research. Assisting him as professional associates are four individuals with master's degrees in the following fields: mechanical and electrical engineering, urban and regional development, business management, and economic analysis; and a fifth associate with a B.A. degree in psychology. Universities also have a competent manpower pool from which to draw for similar research and can utilize student assistants advantageously. Project C-1228 on institutional design for water quality management conducted by the University of Wisconsin may be cited as an example.

This case study of the Wisconsin River Basin is being headed by a professor of urban and regional planning who has an A.M. degree in political science. Assisting him as professional associates are: a Ph.D. in industrial engineering, a Ph.D. in political science and economics who serves as Assistant Professor in Urban and Regional Planning, and an individual working on his M.S. in mechanical engineering.

Student assistants on this project include: (1) a student with an M.S. degree in sanitary engineering and water resources management, currently working on his Ph.D. degree in urban and regional planning; (2) a student with a B.S. degree in mathematics and a M.S. in industrial engineering; (3) a student with a M.S. degree in forestry who is enrolled in a Ph.D. program in forestry; (4) a student currently enrolled in industrial engineering for his Ph.D.; (5) a B.S. student enrolled in industrial engineering; (6) a student with degrees in electrical engineering and statistics who is currently working on his Ph.D. in statistics; (7) a B.S. degree student enrolled in the Law School; and (8) a civil engineer with a B.S. degree.

Dr. E. Stanley Lee of Kansas State University and principal investigator of C-1032 dealing with modeling and optimization of water resources systems, stated that as a by-product of this research, five graduate students had been trained for optimization and systems study of water resources.

In addition to three graduate and one post-doctoral student assisting with project C-1034, "Stochastic Models for Water Resources Management," the principal investigator, D. P. Loucks of Cornell, stated that 26 graduate students successfully completed an advanced course and seminar on stochastic modeling and participated in discussions on results obtained from research undertaken in this project. Seminars were presented to graduate students and faculty at the University of Florida, University of Rhode Island, and Columbia University in addition to Cornell and Harvard Universities.

Two students assisting with project C-1401 by the University of Maryland's Natural Resources Institute - Chesapeake Biological Laboratory, used equipment and limited expendable supplies from the OWRR contract in carrying out work on phytoplankton-nutrient relationships. In this case, the students had NSF-URP (Undergraduate Research Participation) support, but used OWRR equipment. The principal investigator reported this to be an effective means of training students and obtaining valuable research data.

Dr. Frank D. Masch, University of Texas at Austin, principal investigator of project C-1158 dealing with horizontal dispersion in shallow estuaries of irregular shape, commented that the training of student assistants on this project was further enhanced by their occasion to prepare and present papers and to participate in the planning and conduct of, and data reduction from, tests performed on a physical hydraulic model at the U.S. Corps of Engineers Waterways Experiment Station.

Research findings from C-1282, "Computer Analysis of Watershed Characteristics Affecting Flood Hydrology," a study conducted by the University of Kentucky Research Foundation, contributed to the teaching of a course in advance hydrology by the principal investigator.

Professional investigators and student assistants engaged in Title II research are shown by scientific discipline and highest degree held in Table 3. A comparison with investigators on Title I projects can be made by referring to Tables 1 and 2.

Table 3

SCIENTIFIC DISCIPLINES OF INVESTIGATORS OF TITLE II PROJECTS 1968-69

Disciplines of Professional Investigators and Student Assistants	No.of Professional Investigators by Degree				No.of Student Assistants by Degree			
	No degree	Bachelor's	Master's	Doctoral	No degree	Bachelor's	Master's	Doctoral
Aerodynamics			2					
Agriculture						2		
Agronomy					1			
Architecture			1					
Behavioral Science	1			1				
Biology		1	1	1	3			
Business (Admin.)			4					
Chemistry				1		1		
Ecology		1		3	1	1		
Economics		1	6	17		3	3	1
Engineering (Unidentified)	1	3	4	6	2	1	3	
Agriculture		1	1					
Chemical		2	1	7		2		
Civil		6	12	18	5	11	12	
Electrical			3				1	
Environmental			2	2		1		
Fluid Mechanics				4				
Geological		1						
Hydraulics			7	1			1	
Hydrodynamics				3				
Hydrology			1	2				
Industrial				2		2	3	
Mechanical		3	3	1		5		
Sanitary		1	6	6			4	
Water Resources Systems			2	6	1		1	
Forestry							1	
Geography		1						
Geology			1	2	5	1	1	
Industrial Management						3		
Information Science						1		
Law				1		1		
Liberal Arts						1		
Marketing & Transportation				1				
Math (Stat. & Computer Sci.)	1	2	1	6	1	3	1	

Table 3 (Cont.)

Disciplines of Professional Investigators and Student Assistants	No.of Professional Investigators by Degree				No.of Student Assistants by Degree			
	No degree	Bachelor's	Master's	Doctoral	No degree	Bachelor's	Master's	Doctoral
Meteorology		1						
Natural Resources				1			1	
Oceanography			1	5		1		
Operations Research				3				
Physics			1	2	1			
Planning (City & Regional)			1	1			5	
Political Science			2	4				
Psychology				1	2	1		
Public Administration				1		1	4	
Socio-Government		1						
Sociology		4	2	1		1	1	
Soils						3		
Statistics			2	3		1	2	
Water Resources		2	1					
Total	3	31	68	113	22	47	44	1

Attraction of Professional Investigators to the Water Field

Seventy-one trained professional investigators from 28 scientific and engineering disciplines who, heretofore, had not been in the water field, were influenced to engage in water resources research or training in the past year. Much of the credit for this goes to the State institute directors, who see the need to bring the technical competence of investigators from any disciplines to bear on complex and interrelated water problems. These new recruits included 14 engineers of various types; 8 chemists; 8 economists; 6 biologists; 4 statisticians; 3 each of foresters, geographers, lawyers, and sociologists; 2 mathematicians and 2 physicists; and one each of the following: animal scientist, anthropologist, landscape architect, artist, business administrator, agricultural education specialist, environmental scientist, geologist, horticulturalist, expert in industrial administration, marketing specialist, physiologist, regional planner, recreation specialist, and soils professor.

A newly appointed art instructor at the University of Massachusetts, as a result of an OWRR project, has begun a study of attitudes in "inner city" children toward brooks and wetlands as revealed in their drawings and paintings.

An investigator of an Idaho project, who formerly was concerned with farm resources research, is now engaged full-time on water resources research.

Two mathematicians at Clemson University are now working for the first time on a water problem -- development of stochastic models for reservoirs.

A nuclear engineer at North Carolina State University is bringing his expertise in neutron activation analysis to bear on water quality problems.

These examples may suffice to show how people already trained in some scientific discipline, but inexperienced in the water resources field, may be encouraged to help solve water problems, sometimes in conjunction with other specialists on an interdisciplinary or a multidisciplinary basis.

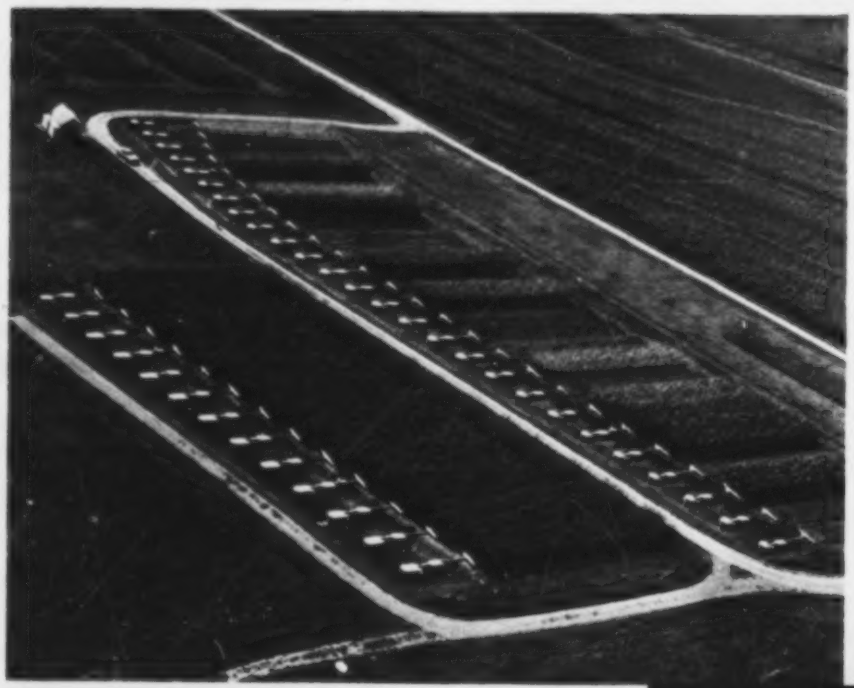
University Response to Need for Improved Training and Research Capability

New Research and Training Facilities

Expansion and improvement of research and training facilities by universities is an important contribution to water resources research and education. P.L. 88-379 funds, in accordance with the Rules and Regulations of the Act are not used to pay the cost of permanent buildings, but they are used for research equipment and supplies needed for approved projects. Universities and the respective States, with assistance from some Federal agencies such as the U.S. Public Health Service, the National Science Foundation and National Institutes of Health, have taken the leadership in building needed new laboratories, greenhouses, flumes, simulated streams, and other facilities for water research and training.

During the past year (1968-69) 39 institutions in 32 States reported construction of, or major addition to, 15 new buildings, completion of some 25 new laboratories, and acquisition or construction of 26 or more other major facilities. The latter included a mobile laboratory, experimental streams, and installation of a telemetry system for connecting field experimental areas with laboratories on campus, thus permitting measurement of variables in rainfall, temperature, streamflow and other factors.

The Universities have responded to the need for improved water resources research and training by adding new faculty members, introducing new courses, and acquiring or constructing new facilities.

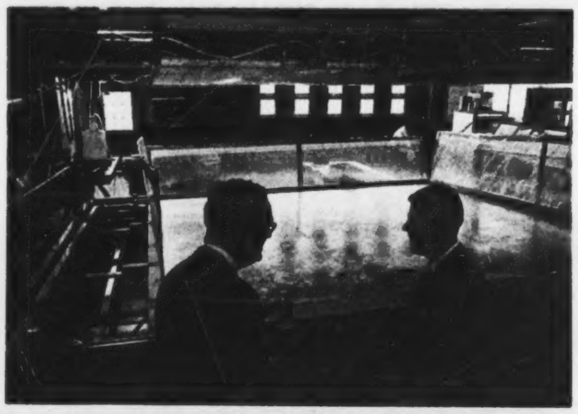


Sediment, pesticides and plant nutrients are water pollutants from agriculture and of concern for water quality in the mid-continent area. These runoff and erosion plots are near McCredie, Missouri. Photo, courtesy Missouri Water Resources Research Center

Research platform used for studies on Bear Lake, Utah-Idaho. The "A" frame and winch in the center permit hoisting of large and heavy objects. Photo by Utah Center for Water Resources Research

The Kit Jones a 65-foot diesel research vessel, is fitted out as a sea-going laboratory. Its research equipment includes a submersible pump which relays water samples to instrumentation on board that can measure and record temperature, pH, salinity, turbidity, oxygen, etc. (B-035-GA)

The network of experimental ponds and the adjacent fisheries laboratories at Cornell University enable scientists to pursue valuable research on biological aspects of water resources. Projects B-011-NY and A-013-NY. Photo, Courtesy New York State College of Agriculture at Cornell University.



Rainfall simulator and instrumented flow table designed to study overland flow on very rough surfaces. Project B-003-IND. Principal Investigator L. F. Higgins on the left.

UNIVERSITY OF MINNESOTA
MOBILE
LAKE STUDY LABORATORY

Mobile Lake Study Laboratory used in the research project A-016-MINN. "Primary productivity of selected Minnesota Lakes"

New Courses Developed

To keep up with changing times and problems, utilize new techniques and facilities, and provide effective training, universities continue to develop and offer new water-related courses. Although development of such courses is not funded by OWRR, some of them are outgrowths of P.L. 88-379-supported research and many have been encouraged by State water resources research institute directors.

During the 1968-69 year, 286 new courses were reported by 61 universities participating in the P.L. 88-379 program. This brings to 1304 the number of new water-related courses reported in the five years since this cooperative Federal-State program was started. Development of these courses has been a major contribution to improved training in the water resources field.

Courses in engineering, including many concerned with systems analysis and environmental problems, again ranked first in number, followed by courses of a biologic nature, geology, atmospheric sciences, ecology, and oceanography. Growing recognition of urban, environmental, and planning problems is reflected in course titles.

The 286 courses developed or offered for the first time in 1968-69 have been grouped in Table 4 into 27 broad categories for comparative purposes.

Most of the State Water Institute schools are members of the Universities Council on Water Resources (UCOWR). Senator Frank E, Moss, Utah is shown here addressing a dinner meeting of UCOWR, Columbia, Missouri. Left to right: Dr. R. E. Peck, Vice President. Research and Graduate Studies, University of Missouri; Dr. Warren Hall, Chairman of Executive Board-UCOWR, University of Calfornia, Riverside; Senator Moss; Dr. Carl Kindsvater, Member, Executive Board, UCOWR, Georgia Tech., Atlanta; and Dr. A. G. Unklesbay, Acting President, University of Missouri.

Table 4

NEW WATER-RELATED COURSES DEVELOPED IN 1968-69

Broad Category and Nature of Courses Developed:			No. of Courses
Agronomy	--		5
Atmospheric Sciences	--	Meteorology, climatology, glaciology	19
Biology	--	Aquatic, micro, radiation	14
Botany	--	Algology, plankton taxonomy, etc.	8
Chemistry	--	Bio, geo, organic, hydro	9
Conservation	--	Natural resources, information	7
Earth Science	--	Geochronology	2
Ecology-Environmental	--	Community, open space, human	15
Economics	--	Agricultural, water, environmental	3
Engineering	--	Civil, sanitary, environmental, agricultural, etc.	101
Forestry	--	Water use, remote sensing, etc.	9
Geography	--	Urban studies, human	2
Geology	--	Hydro, geomorphology, sedimentation	24
Hydrology	--	Geohydrology, etc.	10
Law	--	Natural resources, water	3
Limnology	--		6
Oceanography	--		11
Physics	--	Theoretical, geophysics	4
Planning	--	Resources, State, Budgeting Process	4
Political Science	--	Local government, urban	2
Public Administration	--		1
Sociology	--	Water	1
Soil Science	--		2
Statistics	--		1
Water Resources Science	--		4
Watershed Management	--		2
Zoology	--	Fish and wildlife, entomology, wetlands, etc.	17

No. of Broad Categories Represented, 27; No. of Courses, 286

New Staff Members for Research and Training

Since 1965, over 1300 new staff members have been reported employed by universities participating in Title I research programs in positions where they can contribute to water resources research and training.

Over the past four years four out of every five new staff members employed have gone into new positions. This is indicative of rapid expansion in the water resources field. For Fiscal Year 1969, forty-six of the State Institute universities and 12 other participating universities reported employing 238 new staff members for new positions and 72 people to replace employees who had retired, moved, or died. Thirty-nine (12.6%) of the new employees were supported, in part, by P.L. 88-379 funds. As in past years, most of the new employees held doctoral degrees -- the breakdown in 1969 being 76.4% doctoral, 16.8% masters and 6.8% other degrees, largely bachelors.

New staff members reported employed in the past four years are listed by discipline in Table 5.

Table 5

MAJOR FIELDS OF TRAINING OF UNIVERSITY STAFF MEMBERS REPORTED EMPLOYED

Scientific Disciplines of Employees	No. of New Staff Members Employed				No. of Replacements Employed				Total New Employees Reported			
	1965 1966	1966 1967	1967 1968	1968 1969	1965 1966	1966 1967	1967 1968	1968 1969	1965 1966	1966 1967	1967 1968	1968 1969
Agronomy	5	3	4	1	1	2	3	1	6	5	7	2
Anthropology		1	1							1	1	
Architecture (Landscape)			2								2	
Atmospheric Sciences	3	10	1					1	3	10	1	1
Biology (Incl. micro)	26	21	16	20		4	5	4	26	25	21	24
Botany	1	5	4	5	3	3	1	8	4	8	5	13
Business	3		1	2			1	1	3		2	3
Chemistry	10	15	11	20	3	3	1	4	13	18	12	24
Climatology	1		1		1				2		1	
Ecology	2	6	6	2	2		2	1	4	6	8	3
Economics	17	20	21	15	2	5	3	1	19	25	24	16
Engineering	67	65	59	69	15	18	15	18	82	83	74	87
Environmental Science		3	2	3		1				4	2	3
Ethology		1								1		
Fish and Wildlife	10	6	10	10		3	2	3	10	9	12	13
Food Science		1								1		
Forestry	7	2	5	5	3		1		10	2	6	5
Geography	1	5	5	3	1		1		2	5	6	3
Geology	17	14	13	12	2	9	4	5	19	23	17	17
Government			1								1	
Horticulture		1								1		
Hydrology	10	6	3	5	3	2	2	1	13	8	5	6
Journalism (Agriculture)				1								1
Law	7	2	2	4	1			1	8	2	2	5
Limnology	3	3	2	2	1	2			4	5	2	2

Table 5 (Cont.)

Scientific Disciplines of Employees	No. of New Staff Members Employed				No. of Replacements Employed				Total New Employees Reported			
	1965 1966	1966 1967	1967 1968	1968 1969	1965 1966	1966 1967	1967 1968	1968 1969	1965 1965	1966 1967	1967 1968	1968 1969
Materials Sci.	1								1			
Mathematics			2								2	
Meteorology	6	9	3	5		3	2		6	12	5	5
Mineralogy		5		2		1		1		6		3
Mining			1								1	
Oceanography	2	7	5	10					2	7	5	10
Operations Research				1								1
Petrology		1								1		
Physics (Incl. geophysics)	9	8	8	5	1		1	3	10	8	9	6
Physiology			4				2	4			6	4
Planning	2	2	2	6	2				4	2	2	6
Plant Pathology							1				1	
Political Sci.	3	2	3	4	3	2		3	6	4	3	7
Public Admin.				1								1
Public Health	1	2	3						1	2	3	
Radiology		1								1		
Range Mgmt.			1								1	
Recreation	2		1	1					2		1	1
Resource Dev.				1								1
Sanitary Sci.			1								1	
Seismology		1	1							1	1	
Sociology	6	3	1	2					6	3	1	2
Soil Science	9	7	7	5	4	3	1	3	13	10	8	8
Statistics	1	3	3				1		1	3	4	
Stratigraphy		1								1		
Taxonomy		1								1		
Toxicology						1				1		
Water Resources	2	10		10	1			1	3	10		11
Watershed Mgmt.			1	2				1			1	3
Zoology	15	6	6	6	7	2	1	7	22	8	7	13
Total	249	259	223	238	56	64	50	72	305	323	273	310

P.L. 88-379 Contributions to Student Training

Financial Support

Preceding sections of this report have indicated that in Fiscal Year 1969, 1862 students were employed as research assistants on Title I projects and 114 served as assistants on Title II projects, making a total of 1976 receiving financial support from the P.L. 88-379 program. OWRR funds are not paid directly to students as training stipends. Availability of funds through the respective projects for research assistance however, enables students to gain valuable paid experience while enrolled at a university. Other Federal and State agencies, and, sometimes private industry, often contribute to these or related projects, and their support is acknowledged with thanks and appreciation.

Use of Program Supplies and Equipment

Student benefits through the P.L. 88-379 program are not limited to the support of and use of program equipment by students assisting with discrete OWRR projects. Many other students benefit as a result of equipment used for demonstrating various techniques and in other teaching activities. This is true, particularly, of visual aid equipment, books, desk calculators, and the like, acquired in connection with the P.L. 88-379 program.

In 1968-69, the 51 State institute directors estimated that at their respective universities, and at 27 other participating universities, nearly 4300 students in water-related work made use of such supplies and equipment. Of 4272 students reported in this connection, 2382 were undergraduates, 1159 were candidates for a master's degree, 688 were doctoral candidates, and 43 were post-doctoral students. This indicated use of equipment is another significant contribution of the P.L. 88-379 program to the Nation's academic capabilities for water resources research and training.

Seed Money Effects

A dramatic example of the "seed money" effect in generating needed research took place in North Carolina. To quote from a letter from Director Howells,

> "One of my early efforts was to encourage a research program dealing with the more efficient use of water by industry and the in-plant control of wastes. In working with food processing industries the problem was one of getting together a group, finding someone to provide the leadership, and providing the initial financial support during the project development stage. Dr. Crosswhite assumed this responsibility on behalf of the food processing area and we were then ready to move ahead if the necessary seed money could be found. North Carolina State University provided an initial $6400 and an additional $2500 in Federal funds was provided from the FY 1969 annual allotment.
>
> "Because of its importance to water pollution control, the poultry processing industry was selected for the initial effort. Industrial resistance was high and a prolonged period of plant visits and consultation with industry executives was involved. This finally developed into a full-fledged demonstration project, however, which was funded by FWPCA this year. The total cost is $283,381 with a Federal grant of $198,366.

> "In terms of research generated, the initial annual allotment grant of $2500 can be related to the total level of activity of $292,281 ($283,381 + $6400 + $2500) for a return of $117 for each dollar of annual allotment seed money. There is no question in my mind that this work would not have proceeded in the absence of the initial university and OWRR funding. There was simply too much preparatory work to be done. Now that the work is underway, it is expected to continue and extend into other areas of the food processing industry."

Another example of the seed money or spin-off effects of an allotment project's resulting in greatly increased financial support from other sources is described in Part IV of this report by Montana Center Director, Helmer C. Holje.

Student Enrollment Reported in Water-Related Fields

Directors of the 51 State water resources research institutes have, for the past five years, been requested to provide the best information they can on numbers of students enrolled in water-related curricula in universities participating in the P.L. 88-379 program. Information has been requested, also, on what happens to students following graduation. Such information is not readily available, nor is it strictly comparable from year to year. Interpretation as to what constitutes a water resources student differs with individuals and at different institutions. The number of institutions reporting such information has varied, as has coverage within the institutions' various departments. Hence, the information reported here should be regarded as approximate and interpreted with these reservations in mind.

It would appear, however, that there was a marked increase in numbers of water resources-related students from the 1964-65 to the 1966-67 school years, reported enrollment for those years being 8,958 and 15,117, respectively; then there was a leveling off, or perhaps a decline in total numbers.

For the school year ending June 1968, seventy-six institutions reported an enrollment of 14,406. For the 1968-69 school year, 66 institutions reported 9090 students; however, only 58 of these universities reported Juniors and 63, Seniors. Of the 9090 students, 5739 were undergraduates, 1888 were master's degree candidates, 1139 were doctoral degree candidates, and 24 were post-doctoral students.

Graduates and What Happens to Them

Number Reported Graduating

The State institute directors, with the cooperation of participating universities, reported the graduation of 4978 students -- 2922 with bachelors' degrees, 1581 with masters' degrees, and 475 with doctoral degrees. Over 13 percent of the graduates had received P.L. 88-379 support as research assistants -- 8.1 percent of the bachelors, 19.0 percent of the masters, and 26.8 percent of the doctoral graduates reported.

Status of Graduates

Status of the graduates, insofar as was known at the end of the 1968-69 school year, is shown in Tables 6, 7, and 8. Of 4978 graduates reported, the whereabouts of 1677 (33.7%) were not known. This was particularly true of the bachelors' degree graduates (41.8%), whereas the status of only about one-quarter (25.5%) of the masters' graduates and 11.4 percent of the doctoral degree recipients was unaccounted for by the State directors. Another 7.4 percent or 366 of the graduates were reported as having received non water-related positions or were unemployed. Presumably, some of these two groups have obtained water-related positions subsequent to July 1, 1969.

Of the remaining 59 percent (2935) 47.4 percent obtained water-related positions (35.6% of the bachelors, 48.6% of the masters and 89.8% of the doctoral graduates); 28.9 percent returned to school (32.5% of the bachelors, 31.7% of the masters, and apparently 32 or 8.2 percent of the doctoral graduates obtained post-doctoral assignments); and 23.6 percent went into the military service (31.9% of the bachelors, 19.9% of the masters, and 2.0% of the doctoral degree graduates).

Over the past four years there appears to have been a decrease in the percentage of graduates who obtained positions with Federal agencies and private organizations and an increase in those employed by colleges and universities. The percentage finding employment with State agencies has remained about the same (20% to 21%). Doctoral degree graduates in particular are going into university positions (about 63% of those obtaining water-related positions) where the majority of them (over 70%) divide their time between research and teaching. In contrast, only 5.7 percent of the bachelor degree graduates obtaining full-time water-related positions find employment in universities. This excludes those taking course work who may have fellowships, assistantships, or scholarships. Employment opportunities for both bachelor and master degree graduates appear to be greatest in operations and management-type positions.

Some students who formerly served as research assistants on approved OWRR projects may find employment as professional investigators in their own right a year or so after graduating. No complete record of this is available, but in their 1969 annual reports, 15 State institute directors reported a like number of instances in which former student assistants were now functioning as professional investigators on P.L. 88-379 projects. At least six of these individuals were in States other than that in which they received their training. Trained manpower, like research results, is an important product of this cooperative program.

Table 6

STATUS OF 1968-69 SCHOOL-YEAR GRADUATES

Type of Degree Held by Graduate	No. Employed in Water-Related Positions in:				No. Returning to School for Further Training	No. Going into the Military Service	No. Unemployed or Working in Other Fields	No., Status Unknown	Total
	Federal Agencies	State Agencies	Colleges and Universities	Other, Such as Private Industry					
Bachelors'	164	141	30	191	481	472	223	1220	2922
Masters'	142	115	93	165	338	212	113	403	1581
Doctoral	55	21	220	55	32	8	30	54	475
Total	361	277	343	411	851	692	366	1677	4978

Table 7

TYPES OF WATER-RELATED POSITIONS HELD BY 1968-69 GRADUATES

Type of Degree Held by Graduate	No. of Graduates Engaged in Water-Related Work in:							Total
	Colleges or Universities			Other Organizations, etc.				
	Teaching Primarily	Research Primarily	Research and Teaching	Agency or Private Water Resources Research	Operations and Management	Planning	Other Water Resources Work	
Bachelors'	4	30	3	106	225	87	71	526
Masters'	39	37	36	113	161	78	51	515
Doctoral	32	35	160	71	24	22	7	351
Total	75	102	199	290	410	187	129	1392

Table 8

STATUS OF GRADUATES AS REPORTED AT THE END OF THE SCHOOL YEARS 1965-66 to 1968-69, RESPECTIVELY 1/

Status (Reported in percentages)	1965-66	1966-67	1967-68	1968-69
What Happened to Graduates Whose Whereabouts Were Known 1/				
Water-related positions	49.3	50.3	49.0	47.4
Returned to school	33.2	30.0	26.7	29.0
Military Service	17.5	19.7	24.3	23.6
Types of Water-Related Agencies in Which Graduates Were Employed:				
Private agency, etc.	33.7	31.0	32.2	29.5
Federal	28.9	29.4	26.5	25.9
State	20.8	21.0	20.2	20.0
College and University	16.6	18.6	21.0	24.6

1/ Excluded from this table are those graduates whose status was not known or who were unemployed or working in other fields.

UNIVERSITY OF MISSOURI

Robin Knox, graduate student, Project A-020-MO, is working on a thesis problem on the effect of heat on the growth of fishes. Robin is typical of many graduate students who now face military obligations and are uncertain about completing their graduate program.

Public Involvements at the State Institute and University Level

There is an increasing awareness on the part of State institute directors and other university staff members for improved means of transferring research results and technology to action agencies -- to decision-makers, planners, managers and others who need the information. This awareness was reflected in the recent resolution of the Universities Council on Water Resources (UCOWR) to this end; it is also shown by the many State water commissions, councils, committees and other groups in which institute directors and other university personnel are represented and exercise leadership. Many examples of such public involvement as well as contributions to academia are given in the abbreviated statements of the respective State institute directors in Part IV of this report.

An example or two here may suffice to illustrate approaches being taken to transfer research results or technology to the user in such a way that the research product can be more effectively used.

Thirty-seven North Carolina communities have requested flood information studies from the Corps of Engineers, U. S. Geological Survey or T.V.A.; yet, very little community action has materialized following completion of the studies. The North Carolina Institute sponsored a workshop involving planners, local officials, university faculty, and State and Federal officials on June 6, 1969, to explore problems associated with utilization of Flood Plain Information Reports and implementation of flood plain management plans. Additional steps which might be taken by action agencies and/or research needs were identified.

There is concern that present drainage practices in the Coastal Plain of North Carolina may cause deterioration of one and one-half million acres of organic soils and interference with fish and wildlife habitat and ground water recharge. Development of industrialized farms out of wetland areas increases the dimensions and conflicts in water use. Other agricultural water-use problems in the State include pollution from agricultural chemicals and animal wastes. All of these were discussed at a Workshop on Agricultural and Water Use sponsored by the State Institute on March 14, 1969, involving farmers, county extension chairmen, and water resources research and management personnel. Research on fertilizer loss to surface and ground waters, design of a pesticide monitoring system, and criteria for drainage and irrigation is being sponsored by the Institute (A-031-NC, A-021-NC, and A-033-NC).

To better inform the interested public as well as people directly involved in the water resources field, several of the State institutes -- Alaska, Colorado, Maine and Nebraska -- have, in the past year, started issuing water resources newsletters. Other States, such as Minnesota, North Carolina, and Puerto Rico, have found these newsletters an effective means for disseminating timely information.

Regional Coordination

State institutes, also, are giving increased attention to water problems on a regional basis with a view to improved coordination of research and action programs. Activities of some of these regional groups are discussed here.

In the Midwest there is much concern about agriculture's involvement in polluted and clean water. The Midwest State institute directors at a meeting mentioned in last year's Annual Report, reorganized and formed an expanded institution known as the Mid-Continent State Water Resources Research Organizations. At that meeting the decision was made to hold "A Conference Concerning the Role of Agriculture in Clean Water." This Conference, sponsored by the Mid-Continent group, the Iowa State University and the Federal Water Pollution Control Administration was scheduled to be held at Ames, Iowa, November 18-20, 1969. Funding, in part, will be by the Iowa Community Services under Title I of the Higher Education Act of 1965.

Attending this meeting will be many of the Nation's outstanding authorities to present papers on and discuss sediments, plant nutrients, pesticides and animal wastes as water pollutants. Proceedings will be published and are expected to provide authoritative information on this important problem area for several years.

The 11 Western States have had an active regional organization for several years. On August 25-27, 1969, this group, in cooperation with the Western States Water Council, held the Third Western Interstate Water Conference at Colorado State University. Again, nationally recognized authorities on the program discussed water problems of mutual concern in this region.

Recognizing the need for regional cooperation, the New England Council of Water Center Directors was organized on a formal basis in May, 1966. The general purpose of the Council is to identify and share work on water resources research needs of common interest.

Meetings are held in Boston, Massachusetts, about every four to six weeks and, by invitation during the past year and a half, have frequently included Mr. R. Frank Gregg, Chairman of the New England River Basins Commission and Mr. Chapman Stockford, Executive Director of the New England Governors' Conference. These men have been helpful in planning regional research projects and conferences. A conference on water resources planning was held on May 16-17, 1968 and one on ecology and planning was scheduled for the fall of 1969.

The Council has submitted for possible OWRR support, in the Fiscal Year 1971 Title II program, a proposal entitled, "The Feasibility of Employing a Coordinator to Optimize Multi-University Regional Water Resources Research."

In October of 1968, the Council was officially recognized by the New England Governors' Conference which issued a charter in which it recognized the Council as an organization responsible for formulation and coordination of regional activities relating to its area of specialization. The New England Governors' Conference looks to the Council for advice in identifying specific areas within which the six individual States can:

(a) Exchange views and experience on subjects of general importance to the people of the New England States;

(b) Foster interstate cooperation and regional development;

(c) Attain greater efficiency in State administration; and

(d) Facilitate and improve State-local and State-Federal relationships.

The Charter is signed by the Governors of the six New England States.

The Northeast Association of Water Resources Research Institute Directors has as its members, OWRR institute directors from the six New England States plus New York, New Jersey, Pennsylvania, Maryland, Delaware, Virginia, West Virginia, and Ohio. The main objective of this group has been to make the center or institute directors the best informed individuals on their respective campuses for water resources needs, planning, and management efforts, and for sources of funding for research.

One-day meetings have been held twice yearly with speakers primarily from funding agencies, but, also, from groups such as the New England River Basins Commission in which summaries of their respective programs have been presented, followed by discussion of implications or opportunities for the research centers and vice versa.

The Southeastern institute directors are less formally organized, but individuals do get together to discuss problems of mutual interest.

Publications, Reports and Theses (See Appendix Q)

Publications based on P.L. 88-379-supported projects, or related to work of State water resources research institutes, contribute significantly to the literature in water and related fields. They range from brief leaflets or brochures to books or book-length bulletins, each type fulfilling a need in dissemination of information.

During the year 1968-69, the Title I program produced 574 publications, 370 of them based upon specific annual allotment projects supported, at least in part, by P.L. 88-379 funds; and 157 on matching grant (Section 101) projects. The additional 47 publications were mostly funded with annual allotment moneys but consisted of proceedings of conferences or symposia, the overall institute program, research needs and other program-related matters rather than specific projects.

Emanating from the Title I program, also, were 225 theses and dissertations based on specific projects -- 151 annual allotment and 74 matching grant. Of these unpublished theses, 173 were masters' theses and 52 were doctoral. These are available on interlibrary loan from the respective universities.

Twenty-six Title II projects produced 52 publications, an average of two publications per project, in the past year. In addition, three of the Title II projects resulted in 5 theses -- 1 doctoral, 2 masters and 2 listed as B.S. Honors theses.

A majority of the articles are published in a wide variety of technical and scientific journals. Other outlets are proceedings of conferences and symposia, book publishers, and special publication series of State institutes or university departments. Several of the private research organizations publish their findings independently in sufficient number to satisfy OWRR requirements.

As will be discussed in Part III of this report, the Water Resources Scientific Information Center (WRSIC), managed by OWRR, generated a number of publications in the past year, including the periodic Selected Water Resources Abstracts and a fourth volume of the Water Resources Research Catalog. All of the several publications issued by WRSIC are designed to disseminate water resources information and reduce undesirable replication of research. In total, 11 documents or serial publications were produced by OWRR-WRSIC as an organization and 8 water-related papers were published by individual staff members in OWRR-WRSIC.

Thus, a total of 644 publications or theses was produced by the P.L. 88-379 program in the past year. These are listed in Appendix Q.

A technical completion or termination report is required for each research project supported with P.L. 88-379 funds. A completion report is filed for each project regardless of the number of publications emanating from a project. In Fiscal Year 1969, completion reports on 190 annual allotment projects, 40 matching grant projects and 13 Title II projects were received by OWRR.

In some cases, the completion report represents the primary documentation of research accomplished. In order to assure public availability of these completion reports, which may not be published formally, OWRR forwards copies to the Clearing House for Federal Scientific and Technical Information (CFSTI), Springfield, Virginia 22151. CFSTI serves as a central depository for OWRR-supported technical reports from which requirements subsequent to the initial distribution of these reports can be met. OWRR-WRSIC will issue quarterly lists of OWRR-sponsored reports.

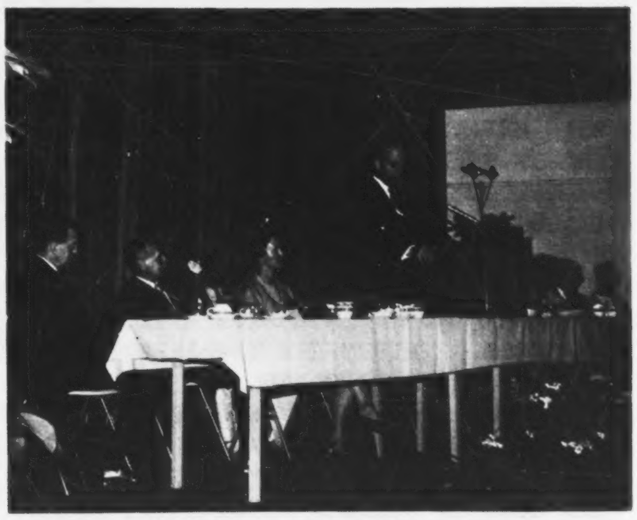
For publications and reports whose availability has not been described in the preceding paragraphs, readers can write directly to the author or to the director of the appropriate State water resources research institute. Addresses of these institutes are given in Appendix S.

In addition to the publications and theses listed in Appendix Q, progress on, and research results from, many projects were presented at various public and scientific meetings during the year.

Television and radio are effective media for bringing popular research results to the public. Director Smith (right) of Missouri discusses water pollution with Paul Bernard of KMOX-TV in St. Louis.

OWRR in the Department of the Interior administers the PL 88-379 programs at the Federal level with less than 40 employees.

Assistant Secretary of Interior, Water Quality and Research, Carl L. Klein (right) E. D. Eaton, Associate Director, OWRR (center), and William S. Butcher, Executive Secretary, Universities Council on Water Resources (left) enroute to South Tahoe Water Reclamation Plant inspection, June 30, 1969. Photo by T. L. Despard, Reno, Nevada



Assistant Secretary Klein addressing the Universities Council on Water Resources, University of Nevada, June 30, 1969. Photo by T. S. Despard, Reno, Nevada

Arthur Witt, Jr. rear) and George E. Smith, Director Missouri Water Resources Research Center (left) explain to OWRR staff member Daniel L. Leedy (right) research being done on effects of heated water discharge from a thermal power plant on a Missouri reservoir. Photo by Robert S. Campbell

PART III

OWRR ACTIVITIES

OWRR ENGAGED IN A NUMBER OF ACTIVITIES IN ADDITION TO ADMINISTRATION OF THE RESEARCH AND TRAINING PROGRAMS. THE FOURTH ANNUAL RESEARCH CONFERENCE WAS HELD; WRSIC EXPANDED THE INFORMATION BASE IN MACHINABLE FORM, IMPROVED USER SERVICES THROUGH SELECTED WATER RESOURCES ABSTRACTS, INDEXES, AND A LIMITED SELECTIVE DISSEMINATION INFORMATION SERVICE, PUBLISHED VOLUME 4 OF THE WATER RESOURCES RESEARCH CATALOG, AND ESTABLISHED 3 ADDITIONAL LITERATURE CENTERS OF COMPETENCE FOR A TOTAL OF 10; OWRR TOOK STEPS TO RESPOND TO THE RECOMMENDATIONS OF THE 1968 ADVISORY PANEL, TO DEVELOP PLANS FOR IMPROVED DISSEMINATION OF RESULTS FROM WATER RESOURCES RESEARCH, AND TO INTENSIFY A TOP-PRIORITY PROGRAM OF RESEARCH ON URBAN WATER RESOURCES. THIRTY-SIX TITLE II PROJECTS WERE SELECTED FOR SUPPORT IN FY 1970 WITH EMPHASIS ON METROPOLITAN WATER PROBLEMS AND SYSTEMS ANALYSIS IN WATER PLANNING AND MANAGEMENT. CONSULTANTS WERE ENGAGED TO PROVIDE STATE-OF-THE-ART REPORTS IN TWO SUBJECT AREAS--ECOLOGICAL CONSIDERATIONS IN WATER RESOURCES MANAGEMENT, AND A GENERAL ASSESSMENT OF SYSTEMS ENGINEERING AS APPLIED TO WATER RESOURCES. SEMINARS WERE HELD ON SYSTEMS SIMULATION, ANALYTICAL SYSTEMS FOR NATIONAL WATER ASSESSMENTS, DISPERSION OF WATER POLLUTANTS, PHYSICAL AND MATHEMATICAL MODELS OF ESTUARIES, ANALYSIS OF SMALL WATERSHED RESPONSES, AND SOIL WATER MOVEMENT. A SYSTEMS APPROACH TO GREAT LAKES RESEARCH WAS INITIATED WITH SUPPORT OF STUDIES AT OHIO STATE, UNIVERSITY OF MICHIGAN, MICHIGAN STATE AND THE UNIVERSITY OF ILLINOIS. THE OWRR STAFF PARTICIPATED IN MANY INTRA- AND INTER-DEPARTMENTAL COMMITTEES CONCERNED WITH WATER RESOURCES PLANNING, RESEARCH AND MANAGEMENT. FUNDS APPROPRIATED FOR THE FY 1969 PROGRAM WERE $5,100,000 FOR ANNUAL ALLOTMENTS, $3,000,000 FOR MATCHING GRANTS, AND $2,000,000 FOR TITLE II. NON-FEDERAL COST PARTICIPATION WAS OVER $7 MILLION.

PART III

OWRR ACTIVITIES

Introduction

The Office of Water Resources Research engages in a variety of activities in administering the program authorized by the Water Resources Research Act of 1964. The main focus of these activities involves research programs established under Titles I and II of the Act which require a continuing cycle of proposal reviews, evaluation, selection, funding, inspection, monitoring, report reviews, accounting, and auditing.

In addition, a number of other activities are undertaken to facilitate communication and coordination, to sharpen the focus on research gaps and to elevate understanding of water resources problems and their potential solutions. Among these activities are: the annual research conference; special seminars and meetings; the Water Resources Scientific Information Center (WRSIC); OWRR's response to recommendations of the Special Advisory Panel; staff participation in affairs of committees concerned with water and related resources; employment of consultants to prepare state-of-the-art reports; and continuing development of the new, top-priority national program of research on urban water resources.

Fourth Annual Water Resources Research Conference

Each year OWRR sponsors a water resources research conference in Washington, D. C. to bring together Institute directors, representatives from other universities, organizations and agencies conducting research supported by OWRR, and guest experts in various fields of water resources.

The Fourth Annual Conference was held in Washington, D. C. on January 28 and 29, 1969. It was attended by two hundred and thirty representatives of universities, private research organizations, industry, and Federal agencies having an interest in the cooperative research program established under P.L. 88-379, as amended, and administered by OWRR. The conference focused primarily on updating the 10-year water resources research program and the transfer of research results. In addition to prepared papers relating to the main conference themes, papers were also presented on multidisciplinary research and on the panel report of the Office of Science and Technology on policy and institutions in water resources research. These presentations were followed by general discussion led by discussion panels.

At an evening meeting The Honorable Howard W. Robison, Representative from New York, gave a talk on prospects of additional legislation dealing with water resources research and was followed by a report by Dr. Dean F. Peterson on the status of the Water for Peace Program. The final afternoon session consisted of a report on activities of the Water Resources Scientific Information Center and brief reports by representatives of the six geographical regions on regional research activities followed by general discussion and adjournment.

Water Resources Scientific Information Center

Introduction

The purpose of the Center is to insure prompt flow of information concerning water research and related accomplishments to the Federal water-resources community including officials engaged in research, management, and development programs; and, thereby, to promote improved communication, dissemination of knowledge, and avoidance of undesirable duplication of research effort.

During the second year of operation, WRSIC concentrated its efforts upon the following specific objectives:

(a) Expansion of the information base in machinable form;

(b) Improvement of user services derived from the information base such as Selected Water Resources Abstracts, its indexes, and a limited SDI service, i.e., a service providing for selective dissemination of information according to the interest of the recipient.

(c) Support of other user services not derived from the information base, such as the Water Resources Research Catalog.

The policy of the Center continues to be implementation of these objectives by coordinating, supplementing, and avoiding duplication of information services, which are supporting water-resources research, engineering, and management needs.

Centers of Competence

The eight literature centers of competence established during 1968, and described in the annual report of 1968, were continued during 1969. These centers include, by subject area, and performing organization:

(a) Ground and surface water hydrology -- Water Resources Division, U.S. Geological Survey.

(b) Hydraulic structures, soils, rock mechanics, and engineering materials--Office of Engineering Reference, U.S. Bureau of Reclamation.

(c) Metropolitan water resources management -- Center for Urban Studies, University of Chicago.

(d) Water law in the Eastern United States -- College of Law, University of Florida.

(e) Policy models for water resources systems -- Department of Water Resources Engineering, Cornell University.

(f) Water Resources economics -- Water Resources Research Institute, Rutgers, the State University of New Jersey.

(g) Eutrophication -- Scientific Information Program in Eutrophication, Water Resources Center, University of Wisconsin.

(h) Water resources in arid lands -- Office of Arid Land Studies, University of Arizona.

In addition, with support of the FWPCA, the WRSIC has established two additional centers of competence in subject areas concerned with problems of water quality. These are:

(i) Thermal pollution -- Department of Sanitary and Water Resources Engineering, Vanderbilt University.

An ongoing research program in thermal pollution, under Dr. Peter A. Krenkel, will scan the literature concerned with chemical and physical aspects of heated effluents and their effects on aquatic life, mixing and dissipation phenomena associated with heated discharge, and the design and economical operation of cooling towers and ponds. Approximately 500 abstracts a year are expected in these subject areas.

(j) Textile wastes -- School of Textiles, North Carolina State University at Raleigh.

This center will scan literature concerned with effects of wastes discharged into water courses as the result of industrial textile operations, and related waste-treatment processes. About 250 abstracts are expected this year in these subject areas.

In the ensuing months, with support from the FWPCA, the WRSIC plans to establish more centers in such subject areas as: water quality requirements for fresh water and marine organisms, coastal pollution, pollution from oil spillage and other hazardous materials, agricultural wastes, and identification of pollutants.

From existing centers, and directly from publication sources of Federal water agencies and other organizations cooperating with the WRSIC, Selected Water Resources Abstracts expects to announce an increasing range of the water-resources literature with approximately 12,000 citations and abstracts this year. Since the Vol. 2, No. 12, June 15 issue of Selected Water Resources Abstracts, the sources for all abstracts in each issue have been itemized on the last page. Certain of the existing centers of competence, enumerated above, performed additional activities, which should be noted. For example, the Scientific Information Program in Eutrophication at the University of Wisconsin has established an operating information center which, in addition to abstracting pertinent literature in eutrophication, provides literature search services, periodic critical reviews, and issues a directory of University faculty and staff in water resources. Monthly issues in a separate format of the eutrophication abstracts furnished to the WRSIC are also available. The Center for Urban Studies, at the University of Chicago, in addition to its literature scanning and abstracting responsibilities, has published a state-of-the-art review in the area of metropolitan water resources management. This publication is described in more detail under the heading of New Publications in Part III of this report.

Systems Studies

(a) Analysis of scientific and technical literature sources for water-resources information:

During this year a contract study (1/) supported by WRSIC analyzed sources, format, and content of 867 serial type publications out of a possible 1,600 such publications which were identified as having, within the course of a publication year, a content with some degree of relevance to information needs of scientists, engineers, managers, and others concerned with effective use of our Nation's water resources.

The analyzed serials, which were divided into eleven purposive types confirmed the expected spread in the subject discipline orientation. General program orientation of the analyzed serials was delineated.

Significant conclusions, related to the 867 serials analyzed, were:

1. There is a high degree of scatter in the appearance of original papers. Eighty percent (80%) of the primary serials contain less than 5 original papers per year in water resources.

2. Current abstracting services and other secondary publications cover only selected portions of the water-resources literature.

3. Nearly two-thirds of the analyzed serials were published in the United States.

4. Approximately one-third of the analyzed serials were published by professional societies, the largest single class of publishers.

An organized data file, continuing detailed information about the analyzed serials, was also provided for WRSIC management purposes.

(b) Identification of information needs in the water-resources community and requirements for making effective use of WRSIC services:

The Water Resources Institute of the Texas A&M University, under a grant from WRSIC, is conducting a field evaluation which, by structured interviews and concise questionnaire forms, is developing data to determine:

1. Effect of identified user characteristics, such as professional training and current occupation, upon information needs;

2. Evaluate two specific services of WRSIC, the Selected Water Resources Abstracts publication, and the Selective Dissemination of Information service; and

3. Evaluate other kinds of information services, and the willingness of potential users to pay for these services.

1/ W. E. Johnanningsmeier et al, Analysis of serials related to water resources, Wolfe Research and Development Corp., Wash., D.C., March, 1969. Available as PB185-706 from the Clearinghouse for Federal Scientific and Technical Information, Springfield, Va. 22151 at $3 per copy, microfiche 65¢.

One thousand five hundred twenty-nine (1,529) in educational institutions, Federal, state and local governments, private consulting engineers and contractors have been either interviewed or been recipients of one-page questionnaires. Results obtained from interviews and questionnaires will be provided in the final report scheduled for the end of calendar year 1969.

(c) Systems design for integrating the water resources subject related abstracts produced by certain discipline-related abstracting services, such as Chemical Abstracts, Biological Abstracts, and Engineering Index into the WRSIC system:

A WRSIC supported consortium study by BioSciences Information Service, Chemical Abstracts Service, and Engineering Index, Inc., was completed during the year. This study described alternative systems for identifying, segregrating, and reformatting water resources related abstracts produced by these major secondary abstracting services, so that these abstracts could be made more effectively a part of the WRSIC system and reduce possible duplication from other WRSIC sources. Recommended alternatives are being evaluated by the WRSIC staff.

Continuing Services

(a) Water Resources Research Catalog, vol. 4:

The Center supported compilation of the largest to-date Water Resources Research Catalog. Issued in August, volume 4 lists 4,501 research projects that are being carried out by 5,749 investigators in 781 institutions with the financial support of 320 organizations including 289 non-Federal.

The latest volume was composed entirely by computer programs, which had been adapted to compose the pages electronically. An example of typographic versatility of this process is the Subject Index representing a marked departure from the format employed in previous volumes.

(b) Selected Water Resources Abstracts

Selected Water Resources Abstracts -- a semimonthly documentation periodical produced by WRSIC has had its first full year of production in its new format and frequency. From the limited distribution to an initial group of Federal agencies and their grantees, circulation of the Abstracts has risen to include all 50 States, Puerto Rico, Guam, and 9 foreign countries. To make the Abstracts available also to the public, this publication may be obtained from the Clearinghouse for Federal Scientific and Technical Information, Springfield, Virginia 22151 (CFSTI) at $22 and $27.50 annual subscription prices, respectively, for domestic and foreign subscribers.

The Abstracts has grown from 1,403 citations listed in 1968 to 10,300 in 1969. In terms of digestion and compression of printed output of original papers for quicker scanning, an estimated 155,000 pages of published research cited in the Abstracts during the year were displayed on less than 1,400 pages or less than 1 percent of the original number of pages.

The category, Water Resources Planning, provided one example of the growing subject matter, author, and organizational diversity. Documents in this category rose from 150 in 1968 to 720 in 1969, being authored in 1969 by individuals affiliated with 300 colleges and universities, 95 Federal agencies, 25 State agencies, and 75 foreign institutions.

The annual cumulated indexes to the semimonthly issues in 1969 make it possible to search and locate information from 77,000 different access points including 45,000 subjects or topics, 22,000 authors, and 10,000 organizations.

(c) Selective Dissemination of Information

A Selective Dissemination of Information (SDI) system in card form, based upon technical information profiles of almost 1,000 recipients, was being furnished through the facilities of the Bureau of Reclamation in Denver by the end of June 1969. Fiscal year 1970 funding levels forced a reevaluation of program priorities and costs, so that upon the basis of expected customer level and high customer unit costs, furnishing of this service was deferred with the last announcement cards reaching recipients in September, 1969.

New Publications

(a) Heated Effluents and Effects on Aquatic Life with Emphasis on Fishes; a bibliography by Edward C. Raney and Bruce W. Manzel, Cornell University, Ithaca, New York, April 1969.

This publication, which was cooperatively supported by the Philadelphia Electric Company, the Water and Marine Resources Center of Cornell University, and the Office of Water Resources Research, provides a third and expanded edition of work begun by Dr. Raney in 1966. The present edition has 1,870 citations arranged in permuted key words of the title sequence with numbered cross references to the second section, which contains the complete bibliographical entry arranged alphabetically by author.

(b) Selected Urban Storm Water Runoff Abstracts; by the Franklin Institute Research Laboratories for the Federal Water Pollution Control Administration, was published for the WRSIC and FWPCA as WP-20-21 of FWPCA's Water Pollution Control Research Series by the Clearinghouse for Federal Scientific and Technical Information.

This publication, which is a compilation of abstracts with subject, author, and corporate agency indexes, covers the subject areas of urban runoff, storm water discharge, storm sewers, and combined sewers. Its contents represent and update an expansion of an annotated bibliography issued in April, 1966, by the Cincinnati Water Research Laboratory. The work was performed by Franklin Institute under contract for the FWPCA. It is published in this edition as specialized subject abstract form, and in the format of Selected Water Resources Abstracts.

(c) Metropolitan Water Resources Management; a state-of-the-art and literature review by Dr. John R. Sheaffer, Center for Urban Studies, University of Chicago, Chicago, Illinois, September, 1969.

This report seeks to delineate the interest area of metropolitan water resource management, and in so doing provide an assessment of the current state-of-the-art. Being a broad subject, and one which is relatively new, it was found that there did not appear to be a general consensus as to what the scope or emphasis of metropolitan water resource management should be.

In an effort to identify the interest area more clearly, a three-phase program was undertaken. The first phase involved delineation of the subject area on theoretical grounds. This phase was based on academic viewpoints presented in the literature that sought to clarify this broad management effort. The second phase involved an identification of the subject area by expert opinion. Here, people active in the field -- consultants, govermental officials, and university researchers -- were called upon to present their views regarding their efforts in metropolitan water resource management. The third phase involved the identification of an empirically derived subject area. Inputs in this phase resulted from an analysis of plans and reports that have been prepared for metropolitan areas. It is, in essence, an internally derived definition.

The three-phase approach used in the report accomplishes two purposes. First, it identifies what researchers believe should be involved in metropolitan water resource management -- a normative delineation. Second, it presents the interest in terms of what persons participating in the field are saying and doing -- a descriptive delineation which is based on the assumption that metropolitan water resources management is what people interested in the management of water in metropolitan areas do. The differentiation between what is articulated and what is written permits one to approach the descriptive delineation from two perspectives. A systematic comparison of results obtained from the three approaches makes it possible to identify any common grounds that may exist regarding the interest area of metropolitan water resource management.

OWRR Response to Recommendations of 1968 Special Advisory Panel

The special advisory panel, convened in November of 1968 to advise on operations of OWRR, is named on page xxi of the 1968 Annual Report. Its report and recommendations are given in full on pages xiii - xx of the 1968 report.

The 1968 panel's recommendations are presented in condensed form here to save space, and are underlined for clarity. OWRR's analysis of progress toward fulfillment of these objectives follows each suggestion.

Budget

OWRR, in fiscal year 1970, ought to be funded in the full amount authorized by the 1964 Act.

Although there was no increase in the FY 1970 appropriation over the previous year, there has been widespread and growing recognition of need for increased funds. The Universities Council on Water Resources, as well as other organizations and distinguished individuals, have expressed concern that expanding research demands require additional OWRR support.

Reports

Future OWRR annual reports should include a comprehensive "overview" statement on water resources activities.

The wisdom of this recommendation has been recognized in the 1969 Annual Report under the section on "Administration and Coordination at the National Level" which includes discussions on use of consultants, cooperation of Goverment agencies, overall coordination, committee activities, and advice from the State institutes.

Manpower

Factual information and analyses are required on personnel needs in water resources work.

This is an extremely difficult subject to analyze. To develop a good basic understanding, OWRR has obtained the services of an experienced consulting organization, Surveys and Research Corporation. This research, being financed as a Title II project, consists of a pilot study with the objective of developing a methodology for estimating supply, utilization, and demand dimensions of trained manpower in the water resources field. Specific consideration is being given to: (1) development of a usable classification of water resources activities; (2) identifying principal employers of trained personnel; and (3) forecasting future demands for personnel.

Public Information

OWRR should add to its staff an "editor-writer."

This has been accomplished. A former journalist, with long experience in public information affairs, has joined the staff. He is presently engaged in studying procedures for more effectively disseminating research results.

The OWRR annual report, or a summary of it, should be distributed to a broader audience.

Another activity being undertaken by the new staff editor-writer is preparation of a condensed and popular version of the 1969 Annual Report for wide circulation to the ever-increasing numbers of persons interested in the Nation's water problems.

The idea of an OWRR-university extension service should be pursued vigorously.

Pursuant to a resolution on this subject from the Universities Council on Water Resources, the matter was brought before the Committee on Water Resources Research. In addition, the idea has been discussed in some detail with representatives of the National Association of State Universities and Land-Grant Colleges. The Chairman of the Water Resources Committee, Chancellor Daniel G. Aldrich, Jr., University of California at Irvine, has been especially helpful in these considerations.

Meanwhile, Associate Director Eaton is serving as Chairman of an ad hoc committee of COWRR to examine the problem. In its first report, the committee covered various significant points --- including target populations, kinds of information involved, pertinent activities currently in effect, and special problems --- and made initial recommendations as to action required.

Further, as mentioned in the Panel's report, careful attention was given the idea at the Fourth Annual Water Resources Research Conference of State institute directors, other interested research personnel, and administrators which was held in Washington, D.C. late in January 1969. A major focus of the Conference was on transfer of research results.

OWRR is encouraged to initiate seminars or workshops on questions of local or regional interest.

To date, funds have not been available to enable OWRR's direct sponsorship in this type of activity. Under Title I of the Act,numerous institute directors have effectively taken the initiative in arranging for conferences and symposia on water-related matters of local, and to some extent regional, interest. For example, three workshops were conducted in North Carolina on the subjects of: agricultural water problems, effect of charges on municipal water consumption and waste disposal, and on flood plain management.

OWRR should take the initiative in arranging, jointly with public and private agencies, periodic national meetings.

As previously stated, budgets thus far have not allowed for expenditures of the magnitude required for such sessions; however, a start has been made in this direction. For example, OWRR collaborated with the Center for Urban Studies, University of Chicago, in sponsorship of a two-day seminar on "Metropolitan Water Resource Management." This type of endeavor will be stepped-up as means to do so become available.

Study should be stimulated on how the provision of incentives can encourage application of cost-saving research results.

It is clearly recognized that scientific information can and does contribute to the capability for dealing effectively with water resources problems, especially as these problems grow in magnitude, complexity, and urgency. While it has not yet been possible to devise the means for provision of incentives to assure application of research results, a first step has been made in a study for OWRR directed by Mr. Harvey Banks, Chairman of the Leeds, Hill, and Jewett organization. The initial report on this work has been received and distributed to each institute director for review and comment. The report gives principal attention to needs of State and local water officials and related consulting engineering personnel for improved communication of scientific and technical information.

Needed Research

More needs to be known about water resources management systems.

A number of research projects are underway in the field of water resources planning and management. Some of these have been selected for description in other parts of this report. OWRR, recognizing that decision-making with regard to water resources management faces large and complex issues in adoption of plans and programs that will effectively and economically advance toward appropriate objectives, will continue its sponsorship of research in this area.

OWRR should support research on water system preconstruction functions, including comparative studies of single or multiple firm handling of both preconstruction phases as well as construction work itself.

This is an area of activity which has been left to agencies with water resources construction and development programs. While it has not as yet been possible for OWRR to mount a substantial research effort on the subject, it is timely for consideration as part of long-range program planning deliberations now taking place in the FCST Committee on Water Resources Research.

Support should be given to research directed at achieving least-cost solutions through use of cost-saving technologies in construction of water systems.

Response to this point must be the same as that immediately above. There is no denying the critical importance of cost efficiency. It should be possible to include pertinent research in our plans for increased emphasis on metropolitan water management problems.

There should be concerted attention to research on opportunities for Federal-State water resources development to advance the Nation's high priority social goals.

Top priority has been accorded this item under two of the major subject areas identified by OWRR for Title II research support in fiscal year 1971. For example, attention is directed to the need for research on problems associated with multiple jurisdictions in metropolitan and regional water resources planning and management. Also, under another priority research subject, consideration is requested for such problems as how institutional arrangements affect the role of the private sector in water resources development needs and how the socio-economic water system should be analyzed in order to understand how the private sector responds to alternative water management institutions.

Regional Research Development

OWRR should continue to assist and encourage the commonality of interests through regional directors' meetings.

As recognized by the Panel, OWRR holds an annual institute directors' conference early in each calendar year to encourage the desired close working relationships. Further, each OWRR staff scientist is assigned "geographic area" monitorship responsibilities for a particular regional block of states so that he may assist in promoting mutual interests among them.

Although it has not been possible to devote OWRR funds to regional conferences of the directors, encouraging progress has been made through formation of a "State Research Centers Ad Hoc Steering Committee" which has served to help provide planning guidance. Also, by means of individual initiative, the eleven contiguous western states have organized a "Western States Institute Directors Association;"

and thirteen eastern states have formed the "Northeast Association of Water Resources Research Institute Directors." These and other similar groups, such as the "Midcontinent Research Directors," are discussed in another section of this report. OWRR will continue to encourage their activities.

Federal-State Relations

OWRR and the State Water Resource Centers ought to develop stronger channels of liaison with river basin commissions and similar organizations.

An encouraging start has been made in this direction. The directors in Massachusetts, New Hampshire, Vermont, Connecticut, Rhode Island, and Maine have associated themselves in "The New England Council of Water Center Directors" which has already established effective working relationships with the New England River Basins Commission. The latter body has been authorized to cooperate with the Council in sharing expenses of a regional research coordinator for implementing future coordinated regional research programs. The feasibility of employing such a coordinator in order to optimize multi-university regional efforts is the subject of a fiscal year 1971 Title II proposal from a principal investigator at the University of Rhode Island on behalf of the Council.

The matching grant program should be utilized to encourage involvement and support of the States in the formulation of projects and policies on new technologies.

The matching grant program is initiated at the State level and is developed by each water research center director. Involvement and support of the States is inherent in the organic Act which requires that at least 50 per cent of the support for such projects must come from non-Federal sources. Response has been excellent from the outset and has been increasing each year for the limited amount of Section 101 funds. A number of research proposals dealing with new technologies concerned with solutions to urgent national problems have been approved for support. Findings thus far achieved in some of the more promising of these are reviewed in Part I of this report under the section entitled "Research Findings and Their Application to Water Problems." Excellent instances of state enthusiasm are to be found in Pennsylvania where a research project is receiving financial support from the State Departments of Commerce and Forests and Waters. In Wisconsin, work begun under Title II is continuing under Section 101 with substantial State dollar-contributions. There are numerous similar examples.

The State Water Resource Centers could help improve communication with their State governments by pointing out the benefits from active participation in and support of the OWRR program.

This action, of course, lies with the Center directors. It is encouraging to observe that communication at the State level is improving substantially each year. An outstanding example, of the many that could be cited, is New Mexico. Dr. H. R. Stucky, director of the Water Resources Research Institute at New Mexico State University, each year is instrumental in arranging a New Mexico Water Conference which receives wide recognition among State legislators. Visible evidence of support for the Institute's water research program is a new building to house these activities, constructed with a State appropriation, soon to be completed on the Las Cruces campus.

Evaluation

Review panels should be established to appraise the quality of funded research.

To accomplish this objective, OWRR has stepped-up use of individual authorities in review of selected research projects. Thus far, it has not been possible to convene an entire panel for this purpose but consideration is being given the idea.

First, it seems advisable to evaluate results of an expanded "state-of-the-art" and "critical review" effort now underway. These activities are covered in detail elsewhere in the report.

Continued emphasis should be placed on "state-of-the-art" reviews.

This is being done along with the addition of "critical reviews" of research accomplishments. This provides greater depth to the evaluation process by obtaining not only extensive literature searches and reviews by professionals concerned with water resources, in general, but also receiving the benefit of recognized authoritative judgment as to specific needs, desired goals, objectives, and priorities for additional research in a particular subject area.

A summary review should be published covering the first five years of the OWRR program, together with an agenda of high-priority problems.

Program accomplishments and planning for the future are a continuing function but publication of a five-year document has not yet been undertaken owing to the substantial manpower and cost involved. As a necessary first step, OWRR has participated in three recent program review deliberations of the Federal Committee on Water Resources Research, namely: (1) A special three-day session comprised of comprehensive, analytical presentations by each member agency covering existing and proposed future research activities; (2) preparation of the soon-to-be released annual report of the Committee which will emphasize accomplishments and indications of need for change in emphasis during the first five years of COWRR's existence; and (3) preliminary considerations in the process of updating the long-range plan for Federal water resources research. When COWRR has completed these actions, or at least has made substantial progress on them, OWRR will be in a better position to proceed effectively on the Panel's recommendation.

Technology Transfer

The Federal Council for Science and Technology/Committee on Water Resources Research has called attention to the need for more effective dissemination of water resources research results and, through an ad hoc assignment, it is exploring the basis for a cooperative program. An interim report adopted by COWRR broadly outlines the nature of the problem and certain initial issues that should be resolved through discussions among representatives of the academic institutions, Federal and State agencies, and others, including practicing professionals and their organizations.1/ Such discussions to date have explored common concerns and means for proceeding.

The COWRR Committee reported need for improved dissemination of water resources research results. The greatly increased magnitude, complexity, and diversity of water resources problems and professional involvement in dealing with them create new needs for access to scientific and technical knowledge that are not adequately met through existing communication channels. The report points out:

> "In recent years, there has been greatly increased attention to activities that are new in their technical aspects and professional involvements. Water resources planning, water quality management and pollution abatement, water resource management in metropolitan environments, management and protection of estuarine areas, lakes, and marshlands, management of heat rejected by thermal-electric generating plants are some examples of water resource activities that

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1/ Dissemination of Water Resources Research Results. December 18, 1968, Interim Report of the Ad Hoc Committee, adopted by FCST/COWRR December 25, 1968. Office of Science and Technology, Washington, D.C.

> involve physical, life, and social scientists and engineers. Technical (and social) aspects of these problems and of proposed solutions are of concern to professional personnel of Federal, state, and local governments and of private enterprises. Properly informed consideration of an action on such matters requires ready access to the results of research - 'ready access' being defined to include availability of technical (and social) information in form that is comprehensible and usable by competent practicing professionals who may not be research specialists."

Closing an information gap is a two-way process--both the generator of information and its receptor must be actively engaged in the process. Often, however, initial impedance may be so great that communication is ineffective without provision of special aids, and this seems to be widely true for research-practitioner communication in the water resources field. Four kinds of action can reduce initial impedance:

1. Identifying scientific information potentially significant for problem-solving.

2. Repackaging such scientific information for ready comprehension by practitioners and other decision-makers.

3. Providing means of communication designed to facilitate ready access and use by both the generator and the recipient of such repackaged information.

4. Facilitating feedback that will alert researchers to the scientific information needs of those involved in resources decisions and actions.

Three activities are reported here which are considered significant, preliminary steps towards closing the information gap:

(a) Universities Council on Water Resources (UCOWR), in its 1968 Annual Meeting, passed a resolution to authorize OWRR and the universities to develop an adequately financed program for interpretation and dissemination of research findings as follows:

> WHEREAS, there is a growing shortage of scientists and technicians in the entire field of water resources, and,
>
> WHEREAS, there is also a rapid build-up of research information at the universities as the result of the expanded overall water research program, which information is not being transmitted to the user public as rapidly as desirable, and,
>
> WHEREAS, the training of scientists in the colleges of agriculture as financed by matching-grants to land grant universities, and the dissemination of research information through an extension service has been extremely effective, and,
>
> WHEREAS, this same concept has recently been endorsed by the Congress of the United States through matching-grants under the Sea Grant College Act.
>
> NOW, THEREFORE, BE IT RESOLVED, that the Universities Council on Water Resources encourage passage of similar authorizations to the Office of Water Resources Research, and the universities, for the development of adequately financed funding and extension matching-grant programs in water resources.

(b) A Plan for A Comprehensive Water Resources Research Exchange System.

Last year's report described in some detail the nature of the contract between

OWRR and Leeds, Hill and Jewett, Inc., to develop a plan for dissemination of results on water resources. These recommendations are currently being studied by OWRR and the 51 Institute Directors with a view toward implementation as soon as personnel and funding limitations permit.

(c) Fourth Annual Water Resources Research Conference.

Although this Conference is reported on elsewhere in this report, a major theme of the Conference concerned information transfer. It is appropriate, therefore, to consider here the significant, relevant ideas on this subject that emerged:

Dr. Ralph Stucky of New Mexico presented the Resolution on Public Education adopted by the Universities Council on Water Resources (UCOWR) at its annual meeting in July 1968. Dr. Stucky also urged that universities make greater use of seminars, conferences, and short courses to dissiminate information and prepare publications designed to stimulate interest in water resources among students at the primary and secondary school level at the time they are planning for their careers and studies in colleges and universities.

Mr. E. D. Eaton, Associate Director of the Office of Water Resources Research, summarized the report of the ad hoc committee established by the Committee on Water Resources Research (COWRR) of the Office of Science and Technology for the purpose of defining the scope and dimension of the problem and recommending a position and course of action for COWRR to take relative to the UCOWR resolution. In the ad hoc committee report it was recognized that new water problems and programs have created new scientific information needs of information users not heretofore considered to be concerned with water resources research results and that new means would have to be developed to meet those needs. The report further recommended that COWRR provide for collaboration among concerned Federal and State agencies and academic and other organizations in developing a mutually accepted basis for cooperative action. The subject report was approved and adopted by COWRR and the ad hoc committee was instructed to explore means for reaching agreement with the several interests -- UCOWR, National Association of State Universities and Land Grant Colleges, such State agencies as have indicated an interest and willingness to participate, professional organizations, and others -- leading to an agreed-upon basis for cooperative action. An exchange of views, hopefully leading to this objective, is now underway.

Mr. Walter M. Newman of the New England River Basins Commission presented a paper on "Closing the Gap Between Research Results and Application." In this paper, it was emphasized that research efforts be relevant and pertinent in solving today's water problems and that research findings be made available sufficiently early to influence present decision making. One means suggested by Mr. Newman of conveying current research results to the planner and implementer would be by initiating a dialogue among researchers, planners, engineers, etc., by means of a "think tank" established at water resources research centers.

Mr. Harvey O. Banks of Leeds, Hill and Jewett, Inc., presented a progess report on an investigation his firm was conducting for the Office of Water Resources Research on "Research Information Exchange Systems." Preliminary findings of the investigation to date indicate that State newsletters containing brief notes on research findings would be highly welcome by practitioners. The second most popular suggestion for disseminating research results was found to be an automatic distribution of completed research reports. Others means of dissemination of information suggested by the investigation included: OWRR and State Institute-sponsored seminars, OWRR-prepared articles for publication in technical magazines, utilization of information dissemination services of professional societies such as ASCE, AWWA, AWRA, etc., and personal contacts between researchers and users.

In the general floor discussion that followed, a number of suggestions were made to improve the effectiveness of research results transfer. Dr. John Dracup of

UCLA proposed wider utilization of short courses of one to two weeks duration that might be presented through university extension programs for the benefit of water resources practitioners. Dr. Don Kirkham of Iowa State University proposed employment of water resources specialists in university extension programs to convey research results to users and the general public. Dr. Ben Ewing of the University of Illinois proposed greater use of the state-of-the-art paper as a means of reaching a wider audience than the short course approach. Dr. William Butcher, then of the University of Nevada, suggested more person-to-person contact between specific users and researchers during both the research planning and prosecution stages. Dr. David Allee of Cornell University encouraged greater use of educational television to reach large public audiences, and Mr. Walter Newman of the New England River Basins Commission suggested a screening process to determine what research results have sufficient practical application to warrant being carried forward to the pilot plant stage that must precede final application.

OWRR Role in Metropolitan Area Water Problems Research

Water scientists, engineers, and planners need to apply some fresh thinking on ways to plan, develop, and manage effectively available water supplies and discharged waste waters in the urban complex. The increasing concentration of people in metropolitan areas with their enormous accretions of wastes, traffic, business, industry, and recreation needs intensifies the demand on our water resources which are essentially fixed in quantity and degrading in quality. What must be done is to make our urban centers more livable, attractive, and economically viable. Clean water in ample supply for domestic, commercial, industrial, and recreational uses can be a significant factor in realizing this goal.

In his news release of July 31, 1969, Secretary Hickel directed OWRR to give top priority to improvement of water resources management in metropolitan areas of the Nation. Both Secretary Hickel and Assistant Secretary Klein stressed the necessity of efficiently and economically meeting water-related requirements if we are to succeed in improving the environment of our cities and urban areas. A planned program prepared in consultation with technical specialists in urban water research and practice will be reviewed and discussed in late 1969 at a national conference of experts to assure the program's technical and practical soundness.

Our 1968 report mentioned a few examples of metropolitan water research projects being supported under OWRR's Title I and Title II programs. Several additional illustrations will describe the wide scope of studies in this field.

Professors Leonard Zobler and George W. Carey of Columbia University and their associates completed their investigation on benefits from integrated water management in the New York metropolitan region which has a water network of over 400 separately managed agencies. Results are described in more detail in Part I of this report. The Battelle Memorial Institute has begun research in the Cleveland area in the evaluation of urban core usage of waterways and shorelines. A two-year study at Cornell University involves a systems analysis of metropolitan water resources. Research is continuing at Purdue University as to the effects of urbanization on the hydrology of watersheds. Work is underway at the University of Washington on comprehensive planning for urban storm water removal. A novel approach by the University of Chicago considers water as a potential organizing concept in urban regions.

In September, 1968, the American Society of Civil Engineers (ASCE) issued their first year report, "Systematic Study and Development of Long-Range Programs of Urban Water Resources Research," (C-1536). This monumental study under the direction of a project steering committee designated by the ASCE Urban Hydrology Research Council coordinated the work of more than 100 professional water specialists representing many diversified areas of experience and training. The report is described in detail in Part I.

This OWRR-sponsored study, together with a companion ASCE project supported by

USGS, "Analysis of National Basic Information Needs in Urban Hydrology," will serve as working and reference documents in the planned intensification of research on management of water resources in the metropolitan-urban environment.

Status of Title II Research and Suggested Priorities for 1971

Status of Program

Title II of the Water Resources Research Act, as amended, authorizes the Secretary of the Interior to make grants and finance contracts and matching or other arrangements with educational institutions, private foundations or other institutions, with private firms and individuals whose training, experience, and qualifications are, in his judgment adequate for the conduct of water research projects, and with local, State and Federal Government agencies, to undertake research into any aspects of water problems related to the mission of the Department of the Interior which he may deem desirable and which are not otherwise being studied.

In 1969, 360 research proposals representing requests for approximately $35 million in Federal funds were received by the Office of Water Resources Research for consideration for support under the Title II provisions of the Act. The Congressional appropriation for the support of fiscal year 1970 Title II projects was $2 million.

Of the 360 research proposals submitted, 36 projects were selected for support. In the projects selected for support emphasis is given to research related to urban and metropolitan water problems and to development and application of systems analysis to water resources problems. Eight projects deal with research related to metropolitan water problems, eight, with systems analysis development and application, and five, with water resources planning and management. In addition, other projects deal with the ecologic impact of water resources development, social objectives in water resources policy, and management of inland lake resources.

Each proposal selected for support deals with a problem specifically identified as worthy of priority research attention by one or more bureaus of the Department of the Interior, by the Water Resources Council, or by the Committee on Water Resources Research of the Federal Council for Science and Technology.

The 36 Title II projects approved for support in Fiscal Year 1970 are listed in Appendix L. Institutions, agencies or research entities shown in parentheses following project titles are responsible for conducting the described research. Examples of research results from Title II projects are included in Part I.

Suggested Priority Areas for Fiscal Year 1971

The Office of Water Resources Research has identified seven major subject areas for primary research support in the Fiscal Year 1971 program. The goal of the Title II program is to encourage and support research on water resources problems receiving inadequate attention, and to bring organizations into the program and open up new research approaches not effectively reached through authorizations provided in Title I.

Major subject areas for primary research support in Fiscal Year 1971 emphasize those subject and problem areas requiring additional research attention recommended by the Federal Council for Science and Technology as set forth in the publication, "A Ten-Year Program of Federal Water Resources Research," issued by the Office of Science and Technology, August 1966. Specific emphasis will also be given to priority research subjects as developed within the Department of the Interior and relating to the Department's broad responsibilities in the areas of water development, management, and protection, and to recommendations of the special panel convened in accordance with the Rules and Regulations to advise the Secretary of the Interior on operations of the Office of Water Resources Research.

On June 16, 1969, a public announcement was released which described major subject areas which would be emphasized in the OWRR Fiscal Year 1971 program. The announcement contained information and instructions for submitting research proposals to OWRR, and a copy of the list of suggested priority research subject areas is shown below.

The Office of Water Resources Research has identified the following major subject areas for primary research support in the Fiscal Year 1971 program. Some examples of specific research topics within these major subject areas are presented to indicate the range of problems needing research. It is not expected that a given research proposal will cover all or necessarily several of these problems. Problems are listed simply as examples of subjects to which research proposals may be related.

(a) Analysis of Planning, Managerial, Financial, Operating and Regulatory Policies of Water Resources Institutions. Analysis of water rights doctrines especially as they affect the process of decision making, user attitudes and water management practices and policies. Research is needed on problems associated with multiple jurisdictions and conflicting objectives in metropolitan and regional water resources planning and management. Also, technological tools for planning water resource development on a regional or basinwide basis may have advanced beyond our institutional capabilities for implementing plans. While the many conflicts, discussions, and negotiations involved in finding acceptable plans are truly part of the democratic process, further understanding of the mechanisms of the process could serve to expedite the implementation phase, thus benefiting all parties concerned. Research goals should be to provide a basis for establishment of improved mechanisms including evaluation of alternative means of augmenting and conserving supply, for water resources planning, implementation of plans, and to improve management effectiveness through lessening of conflicts, uncertainties, and confusion among claimants to the resource.

(b) Water Resources Policy and Political Institutions. Understanding of policy and institutional problems is indispensable to sound water resources management by both the public and private sectors of the Nation. Research is needed on how institutional policy is measured and what policies and institutional arrangements are conducive to sound water management. Among the questions to which research could be directed are those involving current policies and institutions. The river basin as a water management unit needs further evaluation with respect to the compatibility of water resources management objectives and the needs of regional economic development.

How institutional arrangements affect the role of the private sector in water resources development needs to be researched. A very large segment of water resources needs are fulfilled by the private sector. Comprehensive analysis of the socio-economic water system requires understanding of how the private sector responds to alternative water management institutions. How have Federal policies and alternative state tax and regulatory policies affected the private role in the several functional areas of water service? How have Federal and state grant programs influenced the use of private investment capital in the financing of local water development?

(c) Hydrologic Systems Analysis. The application of operations research tools such as mathematical modeling and simulation, optimization and design theory need to be assessed and further explored in relation to hydrologic events and to planning of surface and ground water resources development. Research needs in the area of optimization include a better definition of benefit functions to portray the economic losses incurred during shortages in agricultural, municipal, and industrial water supplies. Rainfall-runoff models applicable to large watersheds and using both deterministic and stochastic approaches are needed. Correlation of mean annual or seasonal runoff with precipitation, evapotranspiration, physiographic and vegetal parameters would be useful in application to similar areas of sparse hydrologic data. Operations research and information theory techniques should be examined for potential application to inflow-outflow problems in hydrology, flood routing, reservoir operation, data network design, automatic control and monitoring of water distribution systems, etc.

(d) Urban and Metropolitan Water Resources Problems. Research is needed on urban hydrology and the effect of man's activities on water. Such research should include evaluation of the impact of urbanization on the frequency of flood peaks, reduction of low flows, decrease in natural ground water accretion, impairment of water quality, erosion, etc.; and development of methodology and technology to cope with such problems. Knowledge of the effects of urbanization on drainage, water quality, stream regimen, water yield and flooding are essential to intelligent development and utilization of metropolitan water resources. A study of public acceptance of alternative sources of municipal water supply should be encouraged. Research is needed to define and quantify social, esthetic, and amenity benefits associated with urban waterfront development, location and recreational use of metropolitan reservoirs, and preservation, protection, and beneficial uses of marshland and estuaries in close proximity to urban regions. Research is needed on the effects of urban encroachment on the upstream watershed, the effects of changing land use patterns, the economic consequences of the conversion of irrigated land to urban uses and the conversion of irrigation water and water rights to municipal and industrial use. Innovative approaches to water-related recreation and open space in the urban environment are needed. Research is needed on methods to reduce the cost of providing water and sewerage service to new housing. The use of "withdrawals" as a measure of water demand can be misleading when the demand-supply balance in water management and planning becomes critical. A new, rigorous definition of "water requirements" (residential, industrial, commercial and public uses) is needed which will take into account the factors of usage, withdrawal, consumption, recycle, returns and dilution.

(e) Environmental Considerations in Water Resources Planning and Management. Increased knowledge of ecological processes and principles and intelligent use of ecological information can result in more enlightened resource planning and management and help maintain or improve the quality of the environment for man's well-being. Planning and management methodologies need to be developed in the context of sound ecology in which man is regarded realistically as part of the ecosystem. The methodologies would provide for use of water and related resources with minimum degradation of the environment or, preferable, improvement of the environment.

Questions will continue to arise regarding the feasibility and capability of restoring degraded environments to a more natural and more balanced state. Of what value is a relatively unpolluted, naturalistic aquatic area in comparison with one which has been enriched by man and used extensively for mass recreation or other purposes? What are the long-term ecologic implications of man's use of an area? What criteria can be used to judge the extent to which an area can be altered without unplanned irreversible changes made in the ecology, such as loss of a rare species of fish?

Research is needed to identify and determine the ecological processes, types, and functioning of aquatic ecosystems with which man can live most harmoniously and to develop means for predicting the ecologic impacts of water development. Special consideration will be given to innovative, but positive and rational approaches to solving current problems or avoiding future water problems involving the quality of of the environment, whether stemming from waste disposal, dredging, filling, drainage, irrigation, or other water development activities. One approach might be development of ecosystem analysis to a point permitting incorporation of ecological information into engineering-economic-legal-political systems analyses. This would enable decision-makers to use ecological information in conjunction with public preferences and socio-economic, political, and legal constraints, and to decide which of several possible alternative courses of action to take.

(f) Evaluation of Economic Importance of Various Uses of Water, Cost Allocation, Cost Sharing, Pricing and Repayment. Allocation of water resources to specific competing uses is made difficult because market pricing techniques customarily do not reflect certain values which are recognized by the public in the areas of recreation and conservation. Study is needed of methods allocating costs among the various functions of multiple purpose water resource projects. Research is needed to develop alternatives to market pricing for quantifying esthetic, recreation and fish and wildlife benefits. Research is needed for improving the methods used in evaluating primary and secondary benefits of municipal, industrial, and agricultural water uses. Also, research is needed to identify recipients of esthetic, amenity and recreation benefits, to establish methods for determining attitudes and public preferences with respect to competing demands on the water resource, and the ability and willingness to pay for such benefits. Currently, economic analysis concentrates heavily on engineering data; no satisfactory way has been developed to introduce social, esthetic, cultural and similar costs into the economic analysis. Research efforts directed to this problem would be beneficial to both planners and resource managers.

(g) Evaluation of Social Objectives in Water Policy. Benefit-cost analysis is the principal tool for analysis of public investment programs, including watershed and water resources programs. It ranks projects and programs only in terms of economic efficiency. Research is needed to determine appropriate alternative objectives and to develop methods to evaluate the benefits in relation to costs for the different objectives, such as alleviation of poverty, improved distribution of population, environmental quality, and other social values.

Use of Consultants

Ecological Considerations in Water Resources Management.

Improved techniques for predicting the response of water-related biological communities to man-induced environmental change is essential to planning for sound resource use. Unwanted side effects from water-development projects and from increased industrialization and urbanization are growing more familiar every day. Yet, reliable prediction techniques that would allow us to forestall or mitigate adverse effects are wanting.

With severe competition for funds among the many pressing water resources problems, it is imperative that the limited allocation of OWRR funds for ecological research be brought to bear on selected aspects of the problem which can contribute to better water management.

As part of continuing effort to bring these needs into sharper focus, arrangements were made in June, 1969, with Dr. Eugene P. Odum, Director of the Institute of Ecology, University of Georgia, to prepare a report for OWRR on the subject: Ecological Considerations in Water Resources Management. Dr. Odum is an internationally known expert in the field of aquatic ecology. His report is scheduled for delivery in December 1969.

This report will include an introductory section to develop, in a broad way, and in terms understandable to informed laymen and administrators, how ecological considerations and methodologies can contribute to enhancing effectiveness of management of water and related resources in an increasingly urban and industrial society.

It will then identify and give priorities to researchable, ecology-related subjects that now appear promising areas for increased attention and emphasis to provide knowledge needed for improving water resources management.

It will include recommendations as to measures under the Water Resources Research Act that might be taken to aid in bringing about needed increases in research identified above, taking into consideration present and projected research programs of other Federal and non-Federal agencies.

A General Assessment of Systems Engineering as Applied to Water Resources

In June, 1969, a contract was signed with Environmental Dynamics, Inc., Los Angeles, California, Dr. John A. Dracup, principal investigator. The objective of this contract is to provide an assessment of the current state of the art in development and application of systems analysis and operations research in planning, design and operation of water resource systems. This assessment will involve analysis of the total water resource system and each of its sub-systems, and objectives, constraints and functional areas of the total system. Each of these components have, to some extent, been analyzed using techniques of systems analysis and operations research. This assessment will stipulate where techniques of systems analysis and operations research have been utilized in the analysis of each of these components and where additional research is required. Typical systems analysis techniques which have been applied to water resource systems include simulation, probability theory, stochastic processes, statistics, game theory, queuing theory, mathematical programming techniques of linear, non-linear and dynamic programming, and multi-level optimization.

Analysis of water and water-related research requirements in the Great Lakes Region

In 1968, we identified kinds of studies in the Great Lakes region recommended in the contract report by the Committee on Institutional Cooperation (CIC), a consortium of 11 major universities in the mid-West. The CIC study group examined research needs and methods conducive to comprehensive water management and related development in the Great Lakes Region. Region, as defined in the report, includes both drainage basin and the influenced service area. In its consideration of methodologies useful in attaining effective water management and development, the study group placed special emphasis on applications of systems analysis and modeling.

A modest start has been made in the utilization of the systems approach to Great Lakes research. Professor Rolf A. Deininger of the University of Michigan, for example, has initiated OWRR-supported research evaluating deterministic and stochastic mathematical models for control of the water supply and lake levels. The purpose is to determine optimal operating strategies, taking into consideration shoreline, navigation, and power interests. Ohio State University scientists are studying the western basin of Lake Erie employing systems analysis to link on-shore economic relationships with in-lake ecological conditions. Begun in FY 1969, this study will develop mathematical models for two major subsystems. These are the economy of the Detroit-Toledo metropolitan area and the in-lake ecological subsystem. Linkages between these subsystems are envisioned as mainly the pollutants and the resulting water quality.

At Michigan State University, research by Professor Marvin E. Stephenson concerns development of suitable models which will quantitatively describe physicochemical, biological, and economic sectors of water resources management within the Grand River system, a major watershed of Lake Michigan.

Beginning in FY 1970, the University of Illinois in cooperation with the Illinois State Water Survey is undertaking a study of the hydrology for models of the Great Lakes. This matching grant project will provide a means for determining effects on lake levels as a consequence of changes in any of the hydrologic factors resulting from management programs.

Seminars and Meetings

During the year, OWRR sponsored or participated in seminars and symposia focusing on critical water resources problems or significant research efforts. These

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presentations and meetings have proven to be effective media for keeping OWRR's professional staff up-to-date in technical fields, in addition to providing an equally valuable service for participating personnel from other Federal and state agencies, and non-governmental research organizations. These meetings also contribute very significantly in coordination and cross-fertilization of related research done by other agencies, sharpens the acuity of particular research and serves to make OWRR's research maximally responsive to the broad spectrum of needs of the Federal water resource community. Some examples are as follows:

Systems Simulation for Management of a Total Water Resource

On April 2, the Texas Water Development Board and its subcontractor Water Resources Engineers, Inc. made a presentation of the progress, problems, and prospects of Project C-1377, "Systems Simulation for Management of a Total Water Resource." The conference drew participants from 10 Federal agencies, several university professors, representatives from private, industrial and research firms, and the technical staff of OWRR. This presentation was not only informative but evoked stimulating discussion and exchange of ideas thus providing valuable feedback for enhancing the research effort.

Analytical Problems and Systems Related to the Assessment of the Nation's Water Resources

On February 28, OWRR and the Water Resources Council jointly sponsored a seminar on Analytical Problems and Systems Related to the Assessment of the Nation's Water Resources. The focus of this seminar was a presentation by Arthur D. Little, Inc, of their progress on an OWRR-supported research study of required data and analytical systems for preparing national water assessments (Project C-1415).

Representatives from virtually every Federal water resources agency attended this seminar, making valuable contributions in the discussion periods. A follow-up symposium was conducted on March 13 to refine and consolidate items not adequately resolved at the previous seminar.

Transport and Dispersion of Water Pollutants

On February 14, Hydronautics of Laurel, Maryland, made a presentation of the progress and prospects of their research project entitled "Experimental and Theoretical Study of the Hydrodynamics of Dispersion in Rivers and Estuaries" (Project C-1290). Attendees included OWRR staff scientists and interested personnel from the U. S. Geological Survey, Federal Water Pollution Control Administration, Army Corps of Engineers, and Maryland Water Resources Research Center.

This presentation provided an excellent forum for discussing the present state of theoretical and practical knowledge fundamental to predicting effects of pollutants in terms of their patterns of dispersion from sources of pollution.

Utilization of Physical and Mathematical Models in Marine Water Resources Research and Management.

Dr. William Hargis, Jr., of the Virginia Institute of Marine Science and four members of his staff gave a seminar in the Interior Building December 5, 1968, for OWRR and interested representatives of several other Interior Bureaus.

The presentation covered progress and results from the OWRR-supported research on the improvement of mathematical and hydraulic modeling with respect to Chesapeake Bay and some of its principal tributaries, especially the James River.

Generalized Analysis of Small Watershed Responses

In continuance of established OWRR policy, on September 22, Dr. Jaime Amorocho of the University of California at Davis conducted a technical seminar on the

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subject "Generalized Analysis of Small Watershed Responses." Approximately 40 scientists and engineers from several agencies attended including the Bureau of Public Roads, Corps of Engineers and the Organization of American States. Dr. Warren A. Hall, incoming Chairman of the Committee on Water Resources Research of the Federal Council for Science and Technology, participated actively in the open discussion. Dr. Amorocho has been principal investigator on several OWRR-sponsored research projects. This year he is on sabbatical leave from the University under an appointment with the Water Resources Division of the Geological Survey.

Soil Water Movement

On October 22, 1969, Dr. Dale Swartzendruber of Purdue University spoke before an audience of interested representatives from Federal agencies on "The Movement of Water into and through Soil." Professor Swartzendruber, a soil physicist, has specialized in laboratory and field research on the quantification and prediction of infiltration rates from measured soil properties and soil-water content. His studies of the infiltration phase of the hydrologic cycle under the allotment and matching grant programs have included the dynamics of water flow through surface crusts or seals and the role and importance of electrical streaming potentials in influencing water infiltration into soil.

Institute Problems

Part 506.5 of the Rules and Regulations of the Act calls for a summary of advice and comments pertaining to needs and problems of the program as expressed by the State Institute Directors in their annual reports. As in previous years, certain problem areas are of widespread occurrence. These are (1) inadequate matching funds, (2) lack of graduate students, and (3) inadequate socio-economic research.

Inadequate Funds

A continuing problem for many institutes is the inability to secure adequate, non-Federal money to match Federal funds under Section 101 of the Act. As a result, many worthwhile proposals from universities with the capability to make a significant contribution towards the solution of serious water resources problems are not submitted. Illinois, Indiana, West Virginia, New Hampshire, Colorado, Nebraska, New Mexico, and Tennessee list this as a major problem.

In addition, several States face a problem in the allotment program due to spiralling research costs and a fixed support base - Illinois, Wyoming, Alabama noted this as an increasingly severe problem.

Lack of Qualified Graduate Students

Several States continue to report difficulties in obtaining qualified graduate students. Drafting of graduate student research assistants into the armed forces through the Selective Service Act has delayed or interrupted some research projects. Dr. Robert A. Lauderdale, Director of the Kentucky Water Resources Institute, mentioned that projects in engineering and the physical or natural sciences had been particularly hard hit in Kentucky and no relief was apparent for Fiscal Year 1970. Another State mentioning a similar problem is South Dakota.

Socio-Economic Research

A perennial and widespread source of concern is the difficulty in initiating and maintaining a desirable level of research in this area despite almost universal conviction that a great deal more emphasis is vital. This neglect is attributed to both a lack of graduate students and lack of interest on the part of social scientists. Among the States listing this as a serious problem are Indiana, New Hampshire, Nebraska, South Dakota, Minnesota, Illinois, and Tennessee.

Other Problems

Until this year, the need for more interdisciplinary research was cited by many institute directors. This year only one State, Indiana, specifically identi-this need as urgent but other indications suggest that it is still a common problem.

The Tennessee Center Director pointed out that few water research proposals are received from Tennessee colleges and universities other than the University of Tennessee and that at the latter institution proposals from such disciplines as law, public administration and planning are not received. Conferences are being held with the respective department heads to discuss this problem. The Indiana Director also reports difficulty in arranging for participation by other universities in the State.

Arizona estimates that the State contribution to the Center's program is more than double the annual allotment. However, only a fraction of this substantial contribution is reported due to the fact that accounting cannot be maintained in the detail required by Federal audits.

In Puerto Rico, the problems encountered in administering the program may be divided into two broad areas: First, as it is not a separate administrative research unit, the Institute must depend on systems and procedures long established at the University of Puerto Rico. These arrangements do not respond to the unique needs of investigators but rather to traditional academic routine. However, good progress is being made in changing old concepts and procedures. The Administration of UPR has been most cooperative in the process of establishing more efficient cost and procurement methods to suit our needs.

Second, the distance from the mainland, the higher costs for everything and the inadequacy of funds, both Federal and Commonwealth, constitute a permanent problem.

Alaska reports a problem due to physical dispersion. With researchers physically located in different departments and laboratories scattered over the campus, a lack of coordination and a dilution of research effort has resulted. Efforts are being made to build up a full-time research staff and have it officed within a contiguous area.

Late notices from OWRR of approval or rejection of research proposals has caused difficulties in Utah. Non-allowance of payment of fringe benefits under OWRR program continues to cause problems for the University Business Office.

In Arizona, it is not legal to pay "fringe benefits" from State funds in connection with any part of an individuals salary that is derived from non-State funds.

Alabama also cites the exclusion of fringe benefits as a problem.

The Director of the University of Hawaii Water Resources Research Center reports that a university coordinating committee, long-requested and much needed, is yet to be established.

Professor Carl Kindsvater, Director of the Georgia Center, points out a subtle problem in this perceptive comment:

> "The P.L. 88-379 program has stimulated increased emphasis on water resources research and education at the participating institutions. No overt attempt has been made to reshape institutional programs specifically to satisfy research priorities associated with the OWRR program. Nevertheless, allotment funds, augmented by State support, have been used to attract previously uninvolved competence to water-related activities. During the past year, faculty members from 12 major divisions at Georgia Tech and 7 at the University of Georgia were engaged in OWRR-sponsored

research. Active research projects reflect a remarkable correlation with FCST-COWRR research priorities. This is partly due to the researcher's pragmatic reaction to priorities established by funding agencies. It is also a result of the fact that the program includes a considerable number of proposals. Included in proposals not approved for funding are some which reflect exceptional research competence which is characteristic of the participating institutions. This observation suggests that one of the purposes of Federal sponsorship of the P.L. 88-379 program should be to combine the best talent and facilities of the Nation into a coherent national program of research. It recognizes that diversity among our Nation's universities is an asset, whereas conformity, imposed by Federal funding patterns, may result in an inferior national program."

Committees and Other Activities

The Directorate and staff of OWRR participate in a great many interdepartmental, departmental and professional standing and ad hoc committees that are concerned with water and related resources. This participation is essential to maintain the three "C's" - coordination, communication, and cooperation.

Some examples of the more significant committee participation are as follows:

Roland R. Renne [1/]
Director

Adviser to National Academy of Sciences' Committee on Water Resources Research

Member, General Administration Board, USDA Graduate School

Member, National Cooperative Forestry Research Committee

President, Federal Professional Association

E. D. Eaton
Associate Director

USDI representative, Federal Council for Science and Technology, Committee on Water Resources Research

Member, USDI, - Interior Committee on Water Resources Research

Member, USDI, - Interior Committee on Research and Development

Chairman, Committee on Water Resources Research - Task Group on Manpower, Training and Facilities

Edward G. Altouney

Guest Lecturer in Water Resources Engineering-Economics, University of Extension, University of California at Los Angeles

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[1/] Dr. Renne resigned as Director May 17, 1969.
Dr. H. Garland Hershey became Director, September 29, 1969.

Logan O. Cowgill

Member, Federal Council for Science and Technology, Committee on Scientific and Technical Information, Panel No. 1 on Operational Techniques and Systems

Member, Water Resources Council, Committee on Hydrology, Bibliography Work Group

Alternate USDI member, U. S. Standards Institute, Z-39 Sectional Committee on Library and Documentation

Chairman, Natural Resources Division, Special Libraries Association

Luther C. Davis, Jr.

Alternate Member, Federal Advisory Committee on Water Data

Glen D. Fulcher

OWRR representative on Economics of Natural Resources Development Committee of the Western Agricultural Economics Research Council

Member, International Relations Committee of the American Society of Range Management

Raymond A. Jensen

Alternate member of the Committee on Scientific and Technical Information (COSATI) of the Federal Council on Science and Technology

Member of COSATI Task Group on dissemination of information

Member of COSATI Panel Six - Information Analysis Center

Member of Sectional Committee Z-39 on Library and Documentation Work of the United States of America Standards Institute

Daniel L. Leedy

Member, Federal Committee on Pest Control

Member, Panel on Natural Resource Science of the Commission on Education in Agriculture and Natural Resources, National Academy of Sciences

Member, Intradepartmental Committee on Recreation and Natural Beauty

Member, NAS-NRC Committee on Interrelationships of Agricultural Land Use and Wildlife Resources

Ljubo Lulich

Member, Washington Computer Center, USGS, Policy Committee, User Group

Albert H. Swartz

Member, Interior Sea Grant Program Liaison Group

Member, Interior Committee for Power Plant Siting Criteria-to Assist Interdepartmental Task Force

Member, Interior National Esutarine Pollution Committee

Member, Steering Committee and Liaison Task Group, Chesapeake Bay Study

Alternate member, Interior Council on Marine Resources

Herbert A. Swenson

Member, National Technical Advisory Committee on Water Quality Criteria

Member, Federal Advisory Committee on Water Data

Member, Committee on Implementation of Open Watershed Research Program

Member, Committee on Water Resources Research - Task Force on Metropolitan Area Water Systems

Stanton J. Ware

Secretary, FCST Committee on Water Resources Research

Chairman, Vector Control Committee, Water Resources Council

Fiscal Aspects of the Program

Federal Funds Provided for Carrying out the Purposes of the Act

Federal funds appropriated to carry out the purposes of the Act from the date of its passage, July 17, 1964, through December 31, 1969, total $50,296,000. The annual appropriations were $3,450,000; $6,396,000; $6,910,000; $11,130,000; $11,181,000, and $11,229,000, respectively, for fiscal years 1965, 1966, 1967, 1968, 1969 and 1970. It has not been necessary to withhold any portion of an appropriation available for allotment to any State.

Funds appropriated for the Fiscal Year 1969 program were $5,100,000 for annual allotments of $100,000 to each of the 51 State institutes; $3,000,000 for 91 matching grants which were awarded to 36 of the institutes; $2,000,000 for 31 contracts and grants under the Title II program; $506,000 for the Water Resources Science Information Center; and $575,000 for expenses of the Office of Water Resources Research.

The amounts of annual allotments and matching grants made to the States and the amounts disbursed to the State institutes in Fiscal Year 1969 are shown in Appendices A and B, respectively; Title II program awards and disbursements in Appendix C; the expenses of WRSIC in Appendix D; the administrative expenses of OWRR in Appendix E; and the status of funds appropriated in prior fiscal years in Appendix F.

The Fiscal Year 1970 appropriation of $11,229,000 provides $5,100,000 for annual allotments of $100,000 to each of the 51 institutes; $3,000,000 for matching grants; $2,000,000 for research grants and contracts under Title II of the Act; $506,000 for the Water Resources Scientific Information Center; and $623,000 for expenses of the Office of Water Resources Research.

Estimated obligations during the calendar year ending December 31, 1969, are shown in Appendices G, H, I, and J.

Non-Federal Support of the Program

The importance of State-Federal cooperation in conducting this program is evident in the substantial amount of non-Federal cost participation in the annual allotment (Section 100) part of the program even though such participation is not a program requirement. The State institute directors were asked, in submitting their Fiscal Year 1969 annual reports, to provide an estimate on non-Federal cost participation as related to this part of the program for the year. A summary of these estimates from the 51 institutes indicated that the non-Federal cost participation exceeded $3,480,000, or about $1.00 for every $1.47 of Federal support.

With respect to the matching grant (Section 101) projects, in which non-Federal moneys, or their equivalent, are required to equal or exceed the Federal funds, the State institute directors estimated expenditures of non-Federal funds to exceed that of Federal funds by $590,000, or about 26 percent more than corresponding Federal expenditures.

Under the Title II program, in which non-Federal contributions are not required, Title II contractors and grantees report the estimated expenditure of $324,025 in non-Federal funds or about $1.00 for every $6.25 of Federal funds spent.

How the Money was Spent

In the 1969 annual allotment program, the institute directors indicated that, of the total Federal funds provided, three-fourths (75.5%) was for salaries and wages; 6.6 percent for non-expendable property, including research equipment; 8.0 percent for supplies and materials and other expendable property; and 9.9 percent for miscellaneous costs such as travel, automatic data processing, and other services.

Of the estimated non-Federal contributions in the annual allotment program, approximately 29.6 percent was in the form of salaries and wages of professional staff who participated in this program; 49.7 percent for indirect costs and employee fringe benefits relating to the allotment program; 16.7 percent for the fair use-value of non-Federal equipment, facilities, etc., used in the program; and 4 percent for other services and costs.

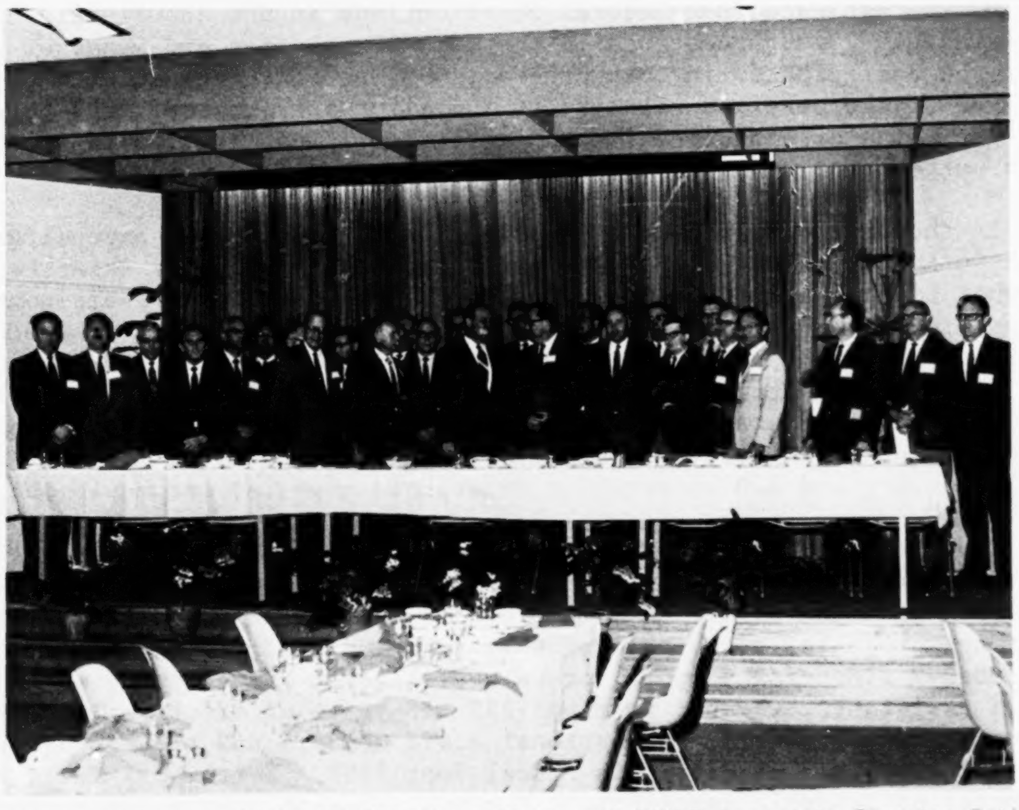
In the cast of matching grant (Section 101) estimated expenditures of Federal funds in Fiscal Year 1969, a high percentage (76.4) was for salaries and wages; a somewhat higher percentage for property (7.9 percent for non-expendable and 7.3 percent for expendable); and a lower percentage, 8.4 percent, for other costs.

Of the non-Federal matching funds provided for Section 101 projects, an estimated 40.8 percent went for salaries and wages; 53.4 percent for indirect and miscellaneous costs including employee fringe benefits; 3.9 percent for non-expendable property; and 1.9 percent for expendable supplies and equipment.

Thus, a high percentage of the Federal funds for both annual allotment and matching grant projects was spent on salaries and wages. Although information on total man-years of effort is incomplete, data available indicate that, for annual allotment projects, principal investigators and professional personnel receiving P.L. 88-379 financial support worked over 115 man-years compared with student research assistants, who put in about 253 man-years of effort. In connection with matching grant projects, professional staff members and student assistants provided over 237 man-years of effort in Fiscal Year 1969. Nearly all Title II research is conducted by academic institutions through research grants and by commercial organizations through research contracts. Reported expenditures of Federal funds for the Title II program in Fiscal Year 1969 show that about 45.6% was for salaries and wages; 1.0% for non-expendable property; 6.2% for supplies and materials; 13.5% for miscellaneous costs; and 33.7% for indirect costs including contract fees.

At the State level, the 51 Water Resources Research Institutes approved under PL 88-379 are focal points in the cooperative research and training program.

Assistant Secretary Klein greeting the State Water Resources Research Institute Directors at the UCOWR meeting in Reno, Nevada. Assistant Secretary Klein on right, Dr. Warren Viessman Jr. of the Nebraska Institute in center, and Professor William G. Walton of the Minnesota Center extending his hand, on left. Associate OWRR Director Eaton in background. Photo by T. L. Despard, Reno, Nevada



Shown here are Assistant Secretary Klein and OWRR Associate Director Eaton of Interior with the Directors of the State Water Resources Research Institutes at a UCOWR meeting in Reno, Nevada June 30, 1969. Highlight reports by the State Directors constitute Part IV of this report. Photo by T. L Despard, Reno, Nevada

PART IV

HIGHLIGHT REPORTS BY THE 51 STATE INSTITUTE DIRECTORS

SECTION 307 OF THE WATER PESOURCES RESEARCH ACT OF 1964 AS AMENDED REQUIRES THAT THE SECRETARY'S ANNUAL REPORT TO THE PRESIDENT AND THE CONGRESS SHALL INCLUDE AN ACCOUNT OF THE WORK OF ALL INSTITUTES FINANCED UNDER SECTION 100 OF THE ACT. IN THIS, AS IN PREVIOUS DEPARTMENTAL REPORTS, THE ANNUAL REPORTS OF THE STATE INSTITUTES OR CENTERS HAVE PROVIDED MOST OF THE INFORMATION CONCERNING P.L. 88-379 ACTIVITIES AT THE STATE AND LOCAL LEVELS. THE INSTITUTE REPORTS SUPPLIED INFORMATION ON RESEARCH, MANPOWER, AND TRAINING ASPECTS INCLUDED IN PARTS I AND II OF THIS REPORT. PART IV OF THIS YEAR'S REPORT CONSISTS OF AN ABBREVIATED STATEMENT BY EACH OF THE 51 STATE INSTITUTE DIRECTORS. THESE REPORTS, REPRODUCED WITH A MINIMUM OF EDITORIAL CHANGES, HIGHLIGHT SOME OF THE WATER-RELATED PROBLEMS IN THE RESPECTIVE STATES, PROVIDE EXAMPLES OF THE RESEARCH BEING DONE ON THESE PROBLEMS, INDICATE WHAT IS LIKELY TO BE THE MAIN THRUST OF THE PROGRAM IN THE NEXT FEW YEARS, AND DESCRIBE SOME OF THE ACADEMIC AND PUBLIC INVOLVEMENTS, AND OTHER P.L. 88-379-RELATED ACTIVITIES DURING THE PAST YEAR. READERS OF THESE STATE-BY-STATE ACCOUNTS WILL APPRECIATE THE DIFFICULTY OF ATTEMPTING TO PRESENT THE HIGHLIGHTS OF THIS DIVERSIFIED COOPERATIVE PROGRAM IN APPROXIMATELY 750 WORDS--THE LENGTH SUGGESTED TO THE STATE DIRECTORS--AND, TO GET MORE DETAILED INFORMATION THAN COULD BE PRESENTED HERE, MAY WISH TO CONTACT THE RESPECTIVE STATE INSTITUTES (SEE APPENDIX S FOR ADDRESSES).

ALABAMA

James C. Warman, Director

Alabama is blessed with abundant rainfall, enormous ground-water storage reservoirs, and extensive systems of rivers and streams. Increasing demands are being made for more clean, fresh water, however, and means must be found for making the maximum beneficial use of this natural resource in order that all segments of society may be given due and equitable consideration in future commitments of the resource.

Alabama's water problems are more correctly described as environmental problems that affect and are affected by human resources, water and land resources, and economic resources. Current and anticipated problems are principally in the areas of water quality management and protection, water resources planning, water quantity management and control, water cycle, and nature of water.

The Institute program will continue to emphasize problem oriented research on water quality (A-004, 011, 012, 016, 017, and B-015, 017 and 028-ALA), planning (A-010, 015-ALA), and quantity (A-005 and B-010, 018, 019, 020, and 025-ALA).

Results from completed project A-008-ALA provide cost information useful to textile plant supervisors in selecting a waste treatment facility and estimating its construction costs. Project B-007-ALA has received world-wide recognition for information on hydrology of limestone terranes and for preparation of an annotated bibliography of over 2000 references, soon to be distributed as part of the program of the International Hydrologic Decade. Project B-012-ALA identified problems and conflicts in water use and control and suggested legislative alternatives in view of present and anticipated problems.

Dr. Daniel L. Leedy of OWRR visited the Institute and was most helpful in his review of research projects at Auburn University, Tuskegee Institute and the University of Alabama March 30 - April 2, 1969. The Water Resources Research Institute, through its Director, was involved in many activities beyond administration of research projects. Mr. Warman was a Member of the Ad Hoc Committee of Directors assisting OWRR in planning its Water Resources Research Conference for January, 1969; and continues as a Member of a three-man Task Force assisting the State Planning and Industrial Development Board in preparation of a comprehensive water and related land resources planning program. He presented papers on (a) results of project B-008-ALA at American Water Resources Association Symposium "Water Balance in North America", June 23-26, 1969, at Banff, Alberta; (b) Federal funding for water pollution control and sanitation at "Seminars in Public Administration" July 29-30, 1968 at Tuskegee Institute; and (c) technical writing at the "State Outdoor Recreation Planning Seminar", March 17-21, 1969 at Auburn University, sponsored by Southeast Council of State Outdoor Recreation Planners, USDI Bureau of Outdoor Recreation, and Auburn University. Mr. Warman served on the committee for selection of U. S. papers for presentation at the International Symposium on Hydrology of Deltas, Bucharest, Romania, May 1969; and on the committee for selection of U. S. papers for presentation at the International Symposium of Land Subsidence, Tokyo, Japan, September 1969; Delegate to UCOWR; on the Board of Directors of the American Water Resources Association; on the Board of Directors and as Secretary of the Technical Division, National Water Well Association, and was appointed Chairman of Technical Division Program for the NWWA Annual Meeting in St. Louis, September 28 - October 1, 1969; Mr. Warman directed the graduate student seminar (AS-690) on effective technical writing during the fall quarter (October - December 1969) for the Department of Agricultural Economics and Rural Sociology, School of Agriculture, Auburn University.

Problems in conduct of the Institute's program center around insufficient funds. Costs of conducting research projects have increased significantly since inception of the Annual Allotment Program under P.L. 88-379, but the Federal funds now available remain fixed at $100,000. Hopefully the Act might also be modified to permit payment of employee benefits.

ALASKA

R. Sage Murphy, Director

Alaska's Water Problems

The water problems within this state can be broadly classified as naturally poor quality and excess quantity during the annual thaw. Remoteness, small populations, and cold weather intensify these problems. However, a turning point in Alaska history occurred in the late summer of 1968 when the North Slope (the coastal plain between the Brooks Range and the Arctic Ocean) oil discoveries were announced. It is a conservative estimate that a tripling of industrial activity will occur within the next five years. Our original water resource problems will not only be intensified, probably as a power function of increased activity, but many new ones will emerge which are only now being assessed.

The opening of the true Arctic, heretofore a geographical area which has never been adequately investigated, has been the focal spot of international oil activity. The creation of all this activity within a 550,000 square mile state which, with a few notable exceptions, is free of pollution and other waste resource problems, is a challenge. It is this challenge the Institute will attempt to meet. Studies will be concerned with all facets of water resources but the primary concern will be to support industrialization while preserving the water quality at a near-natural level.

Institute's Main Thrust

The next five years will be extremely important to the Institute as this will be the period when the industrial expansion mentioned earlier will be in its log growth phase. It is intended that the primary function will be applied research which will be utilized by both industry and state government to augment various water resource plans. Some rather basic work will continue, but the applied area will be predominate in our thinking. It is expected that significant amounts of funding will be available to this organization for water-related research from industrial firms and other agencies in the state and federal governmental structure.

Completed Research

Research which has been completed with project funds from the Office of Water Resources Research can be classified into two categories: a) basic studies which add to the general knowledge of highly specialized fields, and b) applied research which has directly aided in the solution of water resource problems. Of the latter category, several projects have resulted in significant contributions. A few examples are summarized in the following paragraphs.

The study of "Heat Losses in a Circulating Water Distribution System in Sub-Arctic Alaska" (A-018-ALAS) resulted in a well received publication suitable for the use of newly arrived engineers who are not cognizant of such distribution systems. The U. S. Public Health Service, among others, has indicated this manual will be required reading for all their engineers upon arrival in the state.

Research entitled "Biological Degradation of Wastes under Psychrophilic Environments" (A-014-ALAS) has contributed to a better understanding of the microbiological processes taking place during the winter months in Alaska. One of the more significant aspects of the study indicated the activated sludge process is unaffected by low temperatures while the removal rate in streams is.

Other Activities and Accomplishments

In the past the Institute had been largely a clearing house for water related research. It was apparent that coordination of research, scattering of equipment, and the lack of a central organizational structure tended to dilute the research effort. Therefore, our trend will be, from this point forward, to build a full-time research staff, officed within a contiguous area, thus enhancing an interchange of ideas from various disciplines.

The one exception to the above will be a close working arrangement with the Institute of Marine Science, a large research organization located in the same building we occupy. Their well-equipped laboratory and excellent staff have been found to be extremely helpful in our efforts, particularly with respect to some of the estuarine studies with which we are engaged. I foresee a much closer alliance of the two groups in the future. Since they are also a water-oriented group, any cooperation should be beneficial to both groups.

Every professional staff member is engaged in some teaching activity, usually one course at the graduate level. As a group we are also responsible for the undergraduate courses in hydraulics, hydrology, and sanitary engineering. The total teaching load is usually one three-hour course per semester.

An Institute Newsletter was established during the year. This publication is designed to serve a number of purposes, not the least of which is to save money. It is designed to briefly review, in non-technical language, the results of each completed project and the significance of recently funded projects. We believe this approach is important in order to make the general public (including state and national office holders) aware of our research and its significance. In addition, the Newsletter will introduce new staff members, important public speaking events concerned with water, and legislation important to the water resources of Alaska.

We will continue to have our reports published and distributed to the other 50 institutes, but will only mail reports to others if they are requested on an individual basis. It appears, from our first trial edition, that a wider distribution of our work will be effected, and that the total cost of publications will be reduced.

ARIZONA

A. Richard Kassander Jr., Director

Technically, Arizona's water problem is very simple. Politically, economically, and sociologically it is terribly complex. As a simple technical matter, our ground-water reserve is being overdrawn at a rate of approximately 3.5 million acre-feet per year, a rate substantially in excess of 50 per cent of the consumptive use. The result is a continual lowering of the water table resulting in a continual increase in water cost. Over 90 per cent of this water is used for irrigated agriculture, an important source of income to the State's economy. Projections of economic disaster can be made for practically any time period depending on the basic assumptions of the model.

Manufacturing, mining, and tourism are expanding rapidly in the State and the economic benefits per unit of water consumed are enormously greater than for agriculture. However, the mere postulation that agriculture should be replaced by these other activities is meaningless unless it can be accomplished at a greater rate than at present. Moreover, the State's water law does not favor prevention of irrigated agriculture to "bank" the resource for the future.

There are currently rather important moves at the State level to develop an agency responsible for comprehensive State water planning, partly as a result of the U. S. Congressional authorization of the Central Arizona Project. It is to this end that the program of the Water Resources Research Center is designed to be most responsive.

A study of the evolution of the Center's program would reveal that initially it consisted of a number of only coincidentally related projects designed to develop background information in specific areas. Gradually we have attempted to integrate these so that we feel we now have a fairly well balanced program oriented primarily toward planning and management with a good infusion of study of socio-economic factors as well as systems-oriented model building. We anticipate that the next five years will see much more coordination with State planning, depending on the direction in which that moves. We are making additional plans for closer interaction with our advisory group, the Arizona Water Resources Committee, in order to be even more responsive to State problems. All of our projects have been chosen to be focused on the goal of rational comprehensive regional planning and management of the water resource. Some are related to specific gaps which need to be filled to complete the picture.

We cannot give specific examples of completed projects which are being used to solve problems. We can give a number of examples of projects which should be. Although aspects of the project continue, the information and methodology developed under A-008, "Geophysical Investigations," and its earlier counterpart could be used to good advantage. The three phases of "Trace and Tracer Chemicals" and the equipment developed thereunder could find immediate application in management. Gravel-covered plastic catchments under B-005 are ready for application in selected situations.

Our inability to give a more positive answer to this last point and the recognition of need for further interactions in the public benefit have caused our University Advisory Committee to recommend an expansion of the activities of the Director's Office to initiate a program designed to better catalogue local data and information sources so that we can better serve the academic community as well as the public sector. The goal of this will be to get information much more quickly to serve the needs of research as well as application.

During the coming year we hope to start by systematically reviewing the past research accomplishments of the Water Resources Research Center and then devising methods of periodic review of these findings against the requirements for comprehensive planning. This process should first of all considerably reduce the gap between research finding and application because it will enable us to know the opportunities for application. This is not quite as easy as it sometimes appears to be.

A second important result of this process will be to create a feedback mechanism to produce a more rational basis for encouraging and selecting projects in future years.

The process of collecting and cataloguing research data and results and comparing these against a comprehensive water plan, if such is to exist, could easily be a central goal for a five-year program.

The State, through the regular budget of the University, is making a very substantial contribution to the Center's program. We would estimate that our institutional contribution is more than double the allotment grant portion of the program.

ARKANSAS

Aubrey E. Harvey, Director

Because of the large number of streams and rivers in Arkansas, and the relatively recent impoundment of many of the streams, Arkansas' current water problems center around water quality, especially as related to impoundments. Three of the Arkansas Center's projects (A-008-ARK, A-011-ARK and B-002-ARK) deal with methods of assessing water quality, and four projects (A-007-ARK, A-009-ARK, B-002-ARK, B-012-ARK) are concerned specifically with impoundment effects on water quality. Results of these projects are already being used to solve water problems in the State.

Mr. Hinson and Mr. Raible of project A-008-ARK, "Digital Systems for On-Site Data Collections for Water Quality Analysis," have assisted the U.S. Department of the Interior, Fish and Wildlife Service, Stuttgart, Arkansas, in the measurement and control of oxygen for a project relating to consumption of oxygen by fish and with other measurements. Mr. Raible served as a consultant to a project at the University of Arkansas Medical Center concerned with rapid changes of oxygen level in the measurement of reaction rates of flavoenzyme oxidazes. It is of interest, also, that this project produced a water scientist capable of stepping immediately into the position of Director of the Robert S. Kerr Water Resources Center, Ada, Oklahoma.

Dr. Joe Nix, principal investigator of project B-002-ARK, "Distribution of Trace Elements in Impoundments," has consulted with representatives of Southwestern Research Associates of Houston, Texas, regarding their study of the discharge of chloride into Lake Catherine, Arkansas, as a by-product from a Union Carbide vanadium mining operation. The entire staff of this project has cooperated with the Greers Ferry National Fish Hatchery in conjuntion with water quality problems in the hatchery water supply. Recommendations were made for water treatment to reduce the manganese concentration in the water. Dr. Nix also consulted with the Soil Conservation Service personnel concerned with small watershed impoundments built under P.L. 566.

Reports of project B-001-ARK, Water Resources Planning Studies--Arkansas and Oklahoma--have been used by the Arkansas-Oklahoma Compact Committee. This Committee was formed with the specific purpose of apportioning the joint water resources of Arkansas and Oklahoma. Completed project A-002-ARK, "Design and Development of an Automated Sub-Irrigation System," has attracted considerable interest including international inquiries. However, large scale application of this irrigation method has been discouraged pending further research.

Other Center Activities

Principal investigators of most of the Center projects were active in meetings of various technical and scientific societies during the year, many of them presenting papers at these meetings. Public involvements were many and varied. For example, Dr. Testerman of project A-008-ARK assisted the Pulaski County Special School District, Fuller School Complex, in the design criteria on aerobic treatment of sanitary wastes, particularly when the medium is kept at a reasonably constant elevated temperature. Techniques for monitoring properties of wastes by instrumentation were discussed, also, with local civil and electrical engineers.

The principal investigator of project B-002-ARK serves as Chairman, State Committee on Stream Preservation, a committee established by the 1967 Arkansas Legislature. He presented a statement at a public hearing of the Arkansas Pollution Control Commission concerning possible effects of heated water which will be discharged from a nuclear generating facility being constructed on Dardanelle Reservoir.

The Center Director spent considerable time, during the year, in discussions with faculty members of colleges and universities throughout Arkansas regarding possible participation in the P.L. 88-379 program. In developing a Title I program for Fiscal Year 1971, projects from other schools within the State will be considered along with those developed at the University of Arkansas.

CALIFORNIA

Arthur F. Pillsbury, Director

California has a long history of water storage and water transfer schemes; schemes that have solved many problems and have created others. The State, in the face of continued excessive groundwater mining, and large transfer schemes, will, in the future, have to utilize its groundwater basins more to coordinate imported supply with demand, and to provide assurance of continuity of supply in event of disaster. This changing role of groundwater gives rise to a host of problems. Research on inductive electromagnetic methods for mapping and evaluating aquifers is progressing well (B-067-CAL). In another approach, various mathematical models of groundwater basins have been developed. These models are being tested and evaluated for applicability toward a better understanding of the complex Livermore Valley groundwater basin (B-066-CAL).

Other groundwater research projects explore the concepts of optimization through systems analysis for application to the management of groundwater basins. One such project has concentrated on the problems of sea water intrusion into coastal groundwater basins, and is expected to provide design for economic optimization of corrective measures (B-041-CAL). A second project concentrates on optimization of conjunctively managed groundwater basins with emphasis on the pumping and recharge facilities required, and the findings are now being summarized and analyzed (B-006-CAL). A third project, more theoretically oriented and in its early stages, is entitled "System Identification and Multi-Level Optimization of Integrated Groundwater Supplies" (A-033-CAL).

Project A-032-CAL, related to the problem of groundwater basin "salt balance", utilizes mathematical models wherein groundwater dynamics and salinity diffusion are being formulated as two- or three-dimensional partial differential equations with non-linear and time-varying parameters. Solution is being undertaken on a hybrid computer wherein a special analog computer is being developed to be coupled with a digital computer. The equations can be adjusted to the peculiarities of each basin to provide solutions not heretofore possible in defining when and where brackish groundwaters will be encountered.

The problems of cost and effective performance of tile drainage are so important to the future prosperity and environmental quality of California that a two-pronged attack has been developed. One project is studying drainage design as influenced by conditions in the vicinity of the drain line (A-031-CAL), and another deals with physical, chemical, and microbiological factors affecting the discharge of water into drain tile (A-029-CAL). It is visualized that a process for disposing of saline groundwaters by tile drains may be applicable as much to urban as to agricultural lands.

Project B-017-CAL has devised a dynamic input-output and mathematical programming analysis of western regional water resources. It began with basic research on criteria for public policy on developing and allocating water in arid and semiarid regions. It has made excellent progress in application of regional input-output methods of analysis to the California water economy to determine water demand interrelationships. An input-output table has been constructed for the state's economy, growth projections made to the year 1990, and a model constructed for a block of eleven western states. This has led to the forward-looking introduction of a dynamic analytical element into the multiregional model which will enable examination of the economy through several distinct time periods. Widespread interest has been expressed in the results of this research.

California, further, has been in a pioneering position in other aspects of water resources planning research. Project B-001-CAL placed major emphasis on optimization for power generation, with attention to peaking power, and for water releases from the many storage reservoirs involved in the California Water Plan. This effort has been directly utilized by the State in its planning. Project B-061-CAL is placing emphasis on defining critical period hydrology in conjunction with reservoir design and operation, and is utilizing the concept in evaluating possible water deficiencies for project planning purposes.

Other aspects of planning research under way include studies of on-farm irrigation water supplies and costs in relation to cropping systems and production adjustments (B-068-CAL); a comparative study of the use tax as a means of allocation of water resources in a conjunctive use system (A-025-CAL); a study of public attitudes toward reuse of reclaimed water for various purposes (A-030-CAL); an in-depth study of the development of water resources in California in relationship to plans and programs for western regional water development (B-009-CAL); and the allocative impacts of Federal and State water development law (B-065-CAL). These projects are all carefully coordinated to provide the State with the best possible planning information.

Within the limits of this brief description, it is not possible to describe all of the research in progress. The Center maintains close working relationships with the nine major campuses of the University and supports highly selective projects among them to the extent of available funds.

COLORADO

Norman A. Evans, Director

Introduction

Colorado Natural Resources Center activities are concerned with research in water problems facing the State and the Nation; training of water scientists and engineers for the task of research, planning and development; and expediting the flow of communications and exchange of information between those engaged in research and those engaged in application of research.

Colorado Water Problems

A sweeping revision of Colorado laws governing water administration was initiated by the 1969 Colorado General Assembly. The goal is more flexibility in managing the water supply, especially conjunctive surface and ground waters.

To implement and take full advantage of the legislation, new research is necessary. For example, usable techniques will be needed for predicting effects of changes in surface water diversion patterns or in ground water pumping patterns on the total surface-ground water system in a basin. Effects on return flow patterns of local evapotranspiration from crops and phreatophytes will be important. Evaluation of the benefits from winter irrigation as practiced in the Arkansas River basin will be needed to determine if the practice can be discontinued in favor of off-season storage. Effects of agricultural commodity marketing orders and practices on water use patterns need to be determined. Water user attitudes, perceptions, and acceptance of the new mode of water administration should be evaluated.

Environmental quality control will continue to demand research attention and effort. Among the more pressing problems are: salt load control in return flow from irrigated land; feedlot pollution control, waste disposal methods and odor control; domestic waste disposal at mountain recreation and dwelling sites; and reclamation and stablilization of mine tailing dumps to prevent sediment and chemical pollution of surface waters.

Ecological research will play an increasingly important role in Colorado water management planning. Reservoir conditions in high altitude pumped storage systems with special reference to fishery potential is one example where new knowledge is currently needed.

Water supply development and management for the eastern front range area of heavy population and industrial growth will demand accelerated economic, sociological and legal research in view of the limited water supply presently available. Local governments can no longer afford to approach water supply and distribution independently.

New Research to Solve Problems

Allocation of funds for new research is based on relevance to Colorado problems. An advisory committee of representatives from each water-related state agency and the Director of the State Department of Natural Resources assist in identifying major problems.

Waste treatment processes under low temperatures, such as are found in Colorado's mountain communities, will be investigated in Project A-007-COLO. The result will be more reliable treatment plant design criteria for these conditions.

Combined cooling and biotreatment of beet sugar factory condenser effluent will be investigated as a solution to the major water pollution problem still facing that industry. (Project A-008-COLO)

The Colorado water pollution control monitoring and enforcement program, now in its formative stage, will be reviewed by a team of engineers, sociologists, and economists in an effort to provide constructive suggestions for its further development. (Project A-010-COLO) The economic and institutional consequences of water quality standards now in use will be evaluated in Project B-042-COLO.

The effect of new water legislation adopted in 1969 will be studied under Project A-013-COLO to monitor the economic, political, and legal consequences and to identify at an early stage any modifications needed.

New project B-022-COLO will provide important new information about the amount of ground water contributed to alluvial aquifers from underlying bedrock in Colorado river valleys. This knowledge will contribute to the successful management of integrated surface-ground water systems now contemplated under the revised water laws.

Guidelines for assessing water pollution potential of waste effluent disposal at mountain dwelling and recreation sites will be developed under Project B-023-COLO. A basis for classifying waste disposal sites should result.

Research Results in Action

Guidelines to cattle feeders for liquid waste control from feedlots were recently developed by a committe representing feeders, consultants, State Pollution Commission and the Natural Resources Center. Information developed in Project A-001-COLO was utilized.

Extensive application of stream bank stability criteria developed in Projects A-002-COLO and B-014-COLO has been made in planning highway construction through the Rocky Mountains in Colorado and elsewhere to prevent erosion and sediment pollution.

A critique of the efficiency of research and special studies contracted by the State Water Conservation Board over the past several years was one of the results of Project A-005-COLO. Recommendations on future use of this method of obtaining needed data and information were provided to the Board.

Project A-001-COLO produced an inventory of ground water pollution sources and movement in a local problem area which was used for planning purposes by local and state agencies.

Public Service

The Natural Resources Center has sponsored public conferences and symposia to disseminate information on State and National water-related issues. The annual Western Resources Conference is jointly sponsored by the four major State universities doing water resource research. In addition, a State Agency-Resources Center conference is held annually to acquaint agency personnel with current research and to develop closer personal ties among the two groups. Various interdisciplinary committees provide advisory assistance to regional planning bodies in Colorado.

General

The Education Committee of the Natural Resources Center formulated criteria for an interdisciplinary graduate program titled "Natural Resources Administration." Another graduate program is being developed by the Urban and Regional Planning Committee of the Center. This will focus on planning outside the municipal area and will take advantage of established expertise in Forestry, Outdoor Recreation, Fishery, and Wildlife Management at Colorado State University. This program is being coordinated with a developing program in City Planning at the University of Colorado.

Major limitation to water research program growth continues to be lack of adequate matching funds from non-federal sources.

CONNECTICUT

William C. Kennard, Director

Current and Anticipated Water Problems

The principal problem currently facing the State of Connecticut with regard to water is one of quality. In a high rainfall area such as exists in the northeast, it is logical to expect that quality rather than quantity of water is of paramount importance. This problem will become more acute as the population increases (Connecticut is projected to increase from 3,000,000 to nearly 4,000,000 within the next five to 10 years and to 5,000,000 people by the year 2000). Such increases will place additional heavy burdens on the already overtaxed water resources of the State. Similar problems of heavy population densities, increased industrialization and urbanization exist also for the other New England States.

Main Thrust of the Institute Program

We will continue the Institute's broad program of both applied and fundamental research in a wide range of academic disciplines. One new action is of special interest. The Institute, in exploring ways in which the impact on the State of its research activities could be enhanced, decided to "adopt" one river watershed for continuing emphasis. Because of its size and importance in eastern Connecticut and because of its proximity to the campus, the Willimantic-Shetucket River Watershed was selected for this purpose. During the next several years, staff and graduate students in many departments will be encouraged to undertake studies related to this area. The results, thus, not only will have scientific value, but also will be of direct practical value in the future development and use of this important natural resource. One new project (A-026-CONN) will be concerned with algal communities in three sites on the Willimantic River. Additional studies will be activated as resources permit. In our basic research in physics and chemistry we will continue fundamental studies relating to the water molecule itself (A-023-CONN and A-013-CONN). Studies in the engineering sciences will continue with emphasis on fluid mechanics (A-021-CONN), hydrology (A-020-CONN) chemical engineering (A-019-CONN), and sanitary engineering (A-025-CONN). Studies on biology also will be continued (A-027-CONN, A-022-CONN, A-018-CONN, A-014-CONN and A-001-CONN). Further studies on the legal aspects of water management will be conducted under a new project (A-028-CONN) which will be concerned with legal and administrative practices relating to lake pollution. We intend, during the next five years to have the special thrust of the Institute be on studies relating to understanding and abating pollution of the State's surface and ground water supplies.

Completed Research Being Used to Solve Water Problems

Demonstration under A-010-CONN that the reverse filter technique could be used to control erosion has been put to practical use. The rock sausages are being used to direct highway water runoff without soil erosion and in the spillways of dams of several small lakes. Research under A-003-CONN will be used in the management of fish in streams and rivers of Connecticut. The thorough reviews conducted and publications prepared under A-012-CONN will assist, from the legal point of view, in the orderly development of Connecticut's water resources for many years to come.

Other Activities and Accomplishments

The Institute Director, Dr. W. C. Kennard, was a member of a special committee of the Connecticut General Assembly which proposed legislation on the preservation of wetlands. It was adopted in the 1969 session of the Assembly. The seminar program of the Institute was continued with eight lectures being given during 1968-1969. These lectures attracted staff and students from the University as well as people from a wide range of private and public groups and agencies throughout Connecticut. A six-man planning committee was appointed to develop the lecture schedules and speakers for the 1969-1970 academic year. Three of the members are University staff and three are from state and private groups. It is obvious that involvement of people from outside the University will enhance the seminar program. The Institute Director, Dr. W. C. Kennard, was named the University's representative on the Willimantic River Task Force, a group organized recently to focus knowledge and expertise on the problems and potentials of the River. In April 1969, the Institute joined with the Cooperative Extension Service of the University of Connecticut and the Connecticut State Department of Health in conducting a conference on treating and conditioning home water supplies. This was one aspect of the Institute's goal to serve the public and to put to practical use results of pertinent research projects.

The State of Connecticut has continued its significant support of the Institute. Nine graduate students were financed during the academic year 1968-1969 with funds from State sources and two professorial positions were created and filled. State funds also were allotted to the Institute for the purchase of supplies and to pay the cost of essential travel.

DELAWARE

Robert D. Varrin, Director

Current and Anticipated Water Problems

Delaware's water problems result mainly from the rapid expansion of her population and economy in a land area which is limited. The State is undergoing a change from rural-small town to urban-suburban-industrial, i.e., a microcosm of the Nation as a whole. Two phrases which can be heard daily and illustrate the nature of the problem are the urban environment and the changing ecology. Most of the research that the University of Delaware Water Resources Center has and will undertake is directly related to these.

The Northeast United States was subjected to a severe drought during the Sixties. The inadequacy of the water supplies in Delaware was quite apparent, particularly in the northern part. Many solutions have been proposed and they range from the unification of some of the present systems to the importation of water from out-of-state basins. The governmental bodies faced with these decisions do not have the necessary information on which to evaluate the alternatives.

The pollution of the Delaware River and its tributaries is a major regional problem but Delaware's position as the most downstream state and final recipient of the pollution makes this a particular concern. Delaware contributes to this pollution and the over-all solution must begin at home. Newer and better methods for cleaning up our wastes must be found.

Large areas of Delaware can be described as wetlands and many undeveloped valleys still exist in their natural states. Many of these are now directly adjacent to urban areas and encroachment is imminent. Since most of the proposed uses would upset the ecologic balance, the value of these lands as a resource should be evaluated before development for other purposes is allowed.

Research Program Emphasis

The first responsibility of our Center is to the water problems of Delaware and our research program reflects this. Several projects are concerned with the development of means for increasing the dependable water supply. Projects A-004-DEL and B-002-DEL dealt with the ground-water resources of the state, projects A-002-DEL and A-010-DEL looked at ways of increasing water efficiency in the agri-business industry and projects A-003-DEL and A-013-DEL were concerned with economic and governmental aspects of water resources development.

Research has been performed in the area of waste-water treatment. Use of polymers to increase efficiencies in treatment and transportation have been studied in projects A-005-DEL and A-009-DEL, respectively. A method for treating sewage during transit is the subject of project A-008-DEL and a pilot study in the Wilmington system may soon be initiated. The effect of boron on waste treatment is also being studied in A-007-DEL.

The problem of the fresh-salt water balance in Delaware's wetlands is the subject of project A-006-DEL. The role of these lands as food producers to the aquatic life must be better understood.

In the future, the systems approach will be emphasized. Only when its effects on the entire system are known, can a specific problem be analyzed properly.

Accomplishments and Activities

Results of our research effort have already been applied to the solution of water problems or improved water management in Delaware. The Delaware Water and Air Resources Commission is using the ground water studies in their allocation of water. A proposed consolidation of water agencies is based on a report published by our Center. Controversy over the damming of an interstate stream for water supply has been put into better perspective by an economic and engineering study of alternative means of obtaining additional water. The objective viewpoint that is taken by the Center lends great weight to the impact of the conclusions. The decision will now be made with more of the facts known.

The Water Resources Center continues as the focal point for water research, education and information in Delaware. Students trained at Delaware and supported through the Center have gone on to responsible positions in teaching, government and industry. Since each student received support through a research project in which he participated, the applications of the research results should thus find their way into use more readily.

The Water Resources Seminar, sponsored jointly with the Department of Civil Engineering, has and will continue to present well-known speakers on varied water topics. News media report on these seminars and also publish many of our research conclusions. Our image is illustrated by a quote in the Wilmington Evening Journal on research accomplished under project A-003-DEL: "The chief conclusion reached by the professional staff of the university's Water Resources Center is clear and persuasive."

FLORIDA

A. O. Patterson, Director

Florida continues to grow at an astounding rate in permanent population as well as in numbers of visitors to the state. Its summer tourism now rivals that during the winter. The effect on the economy by the possible reduction in the space program at Cape Canaveral seems likely to be more than offset by the private development of the large recreational project some sixty miles west. Citrus and winter vegetables continue to be produced at ever increasing quantities as well as sugar cane and other crops. Cattle production as well is growing steadily. Phosphate mining and the pulp and paper industries continue at high levels. All of these interests combine to put pressure on Florida's water supply which, although abundant, is not unlimited. Moreover, the largest centers of population generally are found along the coasts while the large water supplies are mostly inland.

The present and anticipated water problems of Florida are, and promise to continue to be, problems of distribution, both areal and temporal, and problems of preserving the quality of the supply. The program of the Florida Center is planned to give guidance to those intrusted with water management in meeting their responsiblity in distributing the available water in an optimum manner. For the next five years and longer it is believed the needs of the State can be served best by the Research Center if its aim is to demonstrate ways to determine bases for decisions in water allocation and diversion, examine ways to decrease water use, and concurrently to concentrate on studies toward preventing degradation of the resource in the face of increasing population pressures. The program of the Center now is pointed in these directions. Following are several examples. Maloney's design of a model water use act of the State of Florida (A-009-FLA) will provide the legal approach to water use in the State and Kubat's prediction study of water use by urban and rural areas (A-010-FLA) as well as Reynolds' optimum water allocation study in central and southern Florida (B-005-FLA) both provide guidance in water allocations and the latter two are in the part of Florida that is feeling first the pinch of water shortage because of the fierce competition for water that has developed there. Maloney's book on Florida water law (A-001-FLA) is one of the most comprehensive on state water law in the East and is providing the base for the preparation of the water use act. Myers' examination of ways to reduce water use by improving the efficiency of irrigation methods (A-003-FLA) and West's (A-008-FLA) determination of the influence of inadequate supplies on biological systems are both directed toward decreasing water needs without affecting crop qualities or yields. Some of Florida's lakes are feeling the effects of abnormally high rates of nourishment and are losing their values both as water supplies and as recreation spots.

Putnam's study of factors affecting accelerated eutrophication of Florida's lakes (A-002-FLA) with Brezonik's evaluation of the trophic state of lakes in north-central Florida (B-004-FLA) are expected to reveal possible solutions.

Other activity: George Watkins, graduate student, gave a paper by him and Daniel Kubat (A-010-FLA) before the Florida section, AWWA, at Fort Lauderdale on "Patterns of Water Use by South Florida Households," and Kubat gave a paper, "Awareness of Water Consumption by Socio-Economic Status" at a meeting in Boston of the Rural Sociological Society. Maloney (A-009-FLA) discussed the model water use act for Florida in a speech before a Water Law Conference at the University of Texas in Austin. The paper by Baird, Myers, and Ross (A-003-FLA) "Precision Measurement of Dew Point Changes with Electrolytic Condensation Hydrometer" presented at the 1968 annual meeting of the American Society of Agricultural Engineers has been accepted by ASAE for publication in its Transactions. Cram (A-012-FLA) and Varcoe presented a paper "Gas Chromatographic Separations in Neutron Activation Analysis," as a part of the International Symposium at Gaithersburg, Md. on Modern Trends in Activation Analysis. Dean (A-007-FLA) was selected to serve a six-year term as one of three civilian members of the Corps of Engineers Coastal Engineering Research Board.

The Director gave a talk on Water Resources Research in Florida at the 35th Annual Citrus Growers Institute which was published in The Citrus Industry. He served as co-chairman of an Environmental Engineering Conference on Water held at the University of Florida, which reviewed Florida's water pollution problems, technical and legal methods for controlling them, and the costs. At the conference Morgan (A-002-FLA, B-004-FLA) spoke on Estuarine and Coastal Waters and Brezonik (B-004-FLA) spoke on eutrophication. Dr. Roland R. Renne, then Director of OWRR, spoke on "Urban and Metropolitan Water Resources Problems." The proceedings were distributed to conferees and members of the Florida Legislature. The Director helped update the water section of the University of Florida Institute of Food and Agricultural Sciences' DARE report--Developing Agricultural Resources Effectively--and he served in an advisory capacity to the Florida Section, AWWA Water Resources Committee.

The Florida Center cooperated in bringing to the University of Florida campus Dr. John R. Philip, eminent Australian research scientist, for a special series of lectures on Physics of Infiltration and Micrometeorology.

For the first time since the Center was established the State of Florida offered matching funds to help increase water resources research. With continued help the Florida program will move ahead.

GEORGIA

Carl E. Kindsvater, Director

In Georgia, the most striking characteristic of water resources and water problems is their variety. From cold mountain streams to sluggish tidal estuaries; from regions of negligible groundwater to regions in which the groundwater is almost inexhaustible; from great man-made reservoirs to vast natural swamps; and from sprawling metropolitan and industrial centers to large plantations--Georgia's water resources image is indeed diverse.

The P.L. 88-379 program in Georgia has been based on the facilities, the competence, and the staff interests at two of the largest units of the University System of Georgia--the University of Georgia at Athens, Georgia, and the Georgia Institute of Technology at Atlanta. It is administered through the Water Resources Center at the Georgia Institute of Technology.

The P.L. 88-379 program has stimulated increased emphasis on water resources research and education at the participating institutions. No overt attempt has been made to reshape institutional programs specifically to satisfy research priorities associated with the OWRR program. Nevertheless, allotment funds, augmented by State support, have been used to attract previously uninvolved competence to water-related activities. During the past year, faculty members from 12 major divisions at Georgia Tech and 7 at the University of Georgia were engaged in OWRR-sponsored research. Active research projects reflect a remarkable correlation with FCST-COWR research priorities. This is partly due to the researcher's pragmatic reaction to priorities established by funding agencies. It is also a result of the fact that the program includes a considerable number of Matching-Grant projects which were selected by OWRR from a much larger number of proposals. Included in proposals not approved for funding are some which reflect exceptional research competence which is characteristic of the participating institutions. This observation suggests that one of the purposes of Federal sponsorship of the P.L. 88-379 program should be to combine the best talent and facilities of the Nation into a coherent national program of research. It recognizes that diversity among our Nation's universities is an asset, whereas conformity, imposed by Federal funding patterns, may result in an inferior national program.

Significant accomplishments of the on-going research program include numerous examples of immediate or potential application to local, regional, and national water problems. Project A-002-GA (Eichholz), for example, has demonstrated that changes in the total concentration of dissolved salts and the relative concentration of sodium ions in groundwater could be used to increase or decrease a soil's retention capacity for certain kinds of waste products. Project A-004-GA (Hewlett) has resulted in a much better understanding of the influence of upland source areas on surface and subsurface flows. The results of Project A-006-GA (Carver) were of direct benefit in responding to a request from the Governor to evaluate the effect of tide-water phosphate mining on the Savannah, Georgia, water supply. Another project (B-035-GA, Marland), has demonstrated that the Georgia estuarine environment produces more food energy than any estuarine zone on the eastern seaboard. Long-range planning for industrial water use will be greatly facilitated by a study of the water demands of 44 four-digit industries in North Georgia (A-014-GA, McGregor).

Several Georgia projects have responded to widespread interest in urban water resources. Six hundred copies of a report on the relationship between metropolitan planning and river basin planning (Project B-009-GA, Kelnhofer) have been distributed and a second printing is under consideration. Project B-011-GA (North) has developed information for estimating domestic water demands as a function of price structure and consumer income. Two other projects (B-024-GA and B-045-GA, York) will provide improved measures of public opinion and perception regarding urban water management issues.

Water quality continues to receive major attention. Projects B-012-GA and B-027-GA (Flege) provide a basis for estimating the pollutional effects of textile dye wastes as a function of quantity of fibrous material processed. Another project, B-020-GA (Eichholz) has developed basic information which will result in improved designs for rapid sand filters. Several other projects, in process or near completion, have yielded information needed to improve a variety of design and predictive processes.

Guidance for the P.L. 88-379 (Title I) program in Georgia is provided through the Joint Tech-Georgia Advisory Committee on Water Resources Research. Extramural guidance is provided effectively on an informal basis by maintaining close relations with appropriate local, State, Federal, and regional agencies. Evidence of such relations is the fact that 16 representatives of 8 different agencies took an active part in research-group activities organized around a Title II project (C-1323). Additional evidence is the fact that the Director served on an Advisory Panel for the Georgia State Planning Bureau and as a Consultant to the Southeast Regional Office of the Federal Water Pollution Control Administration. He also directs a research agreement which is administered through the Georgia District Office of the U.S. Geological Survey, and he coordinates a cooperative research agreement between the Water Resources Center and the Southern Branch, Soil and Water Conservation Research Division, Agricultural Research Service, U.S. Department of Agriculture.

Training, particularly graduate education, is an important by-product of the P.L. 88-379 program. In addition, the Water Resources Center at Georgia Tech serves as the coordinating facility for campus-wide graduate programs related to water resources. During the past year, the fifth and final year of a FWPCA training program in Water Resources Engineering was completed, and a new five-year grant for training in Water Resources Planning and Management was approved. With financial support from State and Federal sources, the Center sponsored 13 seminars on water resources topics. A similar role of coordination is played by the Water Resources Division of the Natural Resources Institute at the University of Georgia.

HAWAII

Doak C. Cox, Director

Water Problems in Hawaii

In spite of the impression afforded by lush vegetation, record precipitation rates in rainy areas, and general excellence of public water supplies, a highly developed water-development technology has always been needed in Hawaii to compensate for high geographic variability in precipitation and for lack of surface storage possibilities. Water problems are now compounded by a combination of radical economic and political changes resulting in rapid increases of population and urbanization and a shift from an economy based on agriculture to one in which tourism is a major base.

In the large areas being converted from agricultural to urban use, the water requirements of areas previously under irrigation may be somewhat decreased by the change, but the conservative uses are increased, and in other areas, completely new water supplies must be developed.

The rapidly changing needs intensify inadequacies of the current methods for appraisal of the unusual type of water resources in the islands. For example, in the major ground-water bodies, the Herzberg lenses floating on salt water, almost all of the assumptions required by conventional analytic techniques are violated.

The quality of domestic water for supplies has always been of concern and enviable standards have been maintained in most systems, but the increased emphasis on tourism and recreation has led to a new emphasis on the quality of water resources in general. At the same time, increases in population, increased mechanization in the agricultural industries, and increased industrialization are leading to rapid increases in pollution problems and potential problems.

Increasing urbanization has led to greatly increased flood problems, in part, perhaps, because of increasing rates of rapid runoff and certainly because of encroachment on flood plains and underdesign of flood-passing structures.

The economics of water-resource development have, in many cases, been poorly worked out in the past and the deficiencies are made more serious by the present rapidity of changes. Past legal and institutional relationships are also rendered inadequate by the changes.

Scope of the Water Resources Research Center Program

The future scope of the Water Resources Research Center's contribution toward solution of the water problems of the State is uncertain because of the discrepancy between its objectives and the financial resources so far provided for their fulfillment. The objectives of the Center include its assumption, on behalf of the State, of the major responsibility for basic research on the water resources of the State. Its State appropriative support has, however, fallen far short of the level required to produce a well-rounded program with respect to this objective.

All of the Center projects contribute toward meeting the problems, most of them quite specifically. For example, geophysical studies beginning with a shotgun approach (B-005, 008, 011-HI) and continuing with concentration along especially promising lines (B-015-HI), are designed to increase ground-water exploration capabilities. Studies on water tracing and dating (A-016, 021-HI) are intended to contribute to the understanding of the recharge and hydraulics of ground-water aquifers and other water resources. Pollution studies (A-001-HI, B-010, 012-HI) are laying the basis for an understanding of actual and potential pollutants, their paths and fates, the extent of pollution, and possible controls. Flood studies have been commenced in a pilot project (B-003, 006-HI). Studies of water-resource economics have been begun with the small-scale methodology study on sugar cane irrigation economics (A-012-HI).

Use of Research Results

Already some of the results of research are ready for or actually in practical use. A study of the troublesome color of domestic waters from rain-forest areas (A-013-HI) has clearly indicated applicable treatments. Studies of resistivity have not only indicated the applicability of this geophysical exploration method under certain Hawaiian ground-water conditions, but have led to application through the interest of the State's Department of Land and Natural Resources and other agencies along a considerable part of the dry western coast of the island of Hawaii and in the Kau area of southeastern Hawaii to a pilot well-drilling campaign. Initial studies of bacterial and viral transmission through soils and rocks (A-001-HI) have indicated that, although the bacteria and larger viruses are effectively removed, the very small Poliovirus Type 2 is not, indicating necessity for concern with the quality of domestic supplies from ground-water sources hitherto considered quite safe.

Community and Academic Involvement

A semi-monthly series of water resources seminars begun by the Center in 1968-69 proved of considerable interest to the wider community as well as University faculty and students. After a two-session summary of the knowledge and deficiencies in knowledge on Hawaiian water resources, the series continued on a variety of topics ranging from the work on viral contamination to the role of industrial-agronomic complexes based on nuclear power and water desalting.

Contributions by members of the Center staff to governmental, professional, and community conferences, local and national, are too numerous to detail here.

The effectiveness of the Center's program has been greatly extended by the provision of project support by the State and County agencies, particularly the Department of Land and Natural Resources and the Honolulu Board of Water Supply, as well as by the Federal Water Pollution Control Administration, which funded a major study of estuarine pollution in the State. The community Advisory Committee on Water Resources has continued to function effectively but a long-requested and a much-needed University coordinating committee has yet to be established.

IDAHO

C. C. Warnick, Director

The University of Idaho Water Resources Research Institute recognizes that key water problems facing the State and Region are: (1) the need to determine the value of certain rivers for inclusion in the National Wild and Scenic River System and the need to perserve water and water areas in a quality state for future generations; (2) the impact of large water developments such as Dworshak Dam and the proposed High Mountain Sheep Dam on the ecology, economic growth and social patterns of the State; (3) the timing and wisdom of developing irrigable lands in the State under the threat of transferring waters to other regions; and (4) the need to study the extent and development of ground water with emphasis on the great Snake River Plain aquifer. Additional needs center around water quality and retention of a pleasing environment through studies of streams and lakes that have been polluted and those that might become polluted. Typical areas receiving considerable attention in the news and public decision arena are the White Cloud Recreational Area in the Salmon River drainage and Mallard-Larkin Pioneer Recreation area in the Bitteroot Mountains. Of continuing concern will be problems associated with water law, water institutions, and water and land development agencies involving local governments, as well as the complex federal-state relations.

A main thrust of the Institute program will be in studies related to Wild and Scenic Rivers as now being funded under Matching Grant Project B-014-IDA and supported by the Idaho Water Resource Board, and other state agencies. The Institute has organized a Scenic Rivers Study Unit to meet this need. This interdisciplinary group includes economists, geographers, foresters, engineers, and biologists working as a unit with graduate students of different professional background to study the methodology for evaluating the need and desirability of wild rivers. The local, state, regional and national viewpoint is being researched on conventional resource items, as well as esthetic and sociological values. Professor Warnick, as Institute Director, has been named by Governor Samuelson to serve as the State's representative in discussions on wild rivers. Support from the State has been an encouraging sign that the State, with limited financing for research, has recognized the importance of this issue.

Great emphasis has been made to develop capability in ground water studies. Project A-021-IDA, a study of the variability of water quality in the unsaturated zone of soils above the water table, now being completed, gives insight on movement of water to local aquifers. Two other projects directly related to ground water were initiated during the year: Project A-023-IDA, concerned with seepage and natural sealing phenomenon of silt and biological activity in irrigation canals; and Project A-025-IDA, a study of the effect of physical properties of soil on ground water movement.

Studies concerned with limnology of high mountain lakes, Project A-018-IDA completed in the fall of 1968 and Project A-022-IDA completed in June 1969 on effects of physical and biotic environment on aquatic insects in the St. Maries River, are contributing to a better understanding of ecology in the water environment and knowledge of how to preserve water areas for future generations.

The Institute realizes that part of the program must entail basic research and the projects in Forestry are pointed in this direction. A project being completed this summer (A-014-IDA) is concerned with the energy balance and evapotranspiration processes of forest and range lands of Idaho. Matching Grant Project B-009-IDA initiated in 1968 is a study of a simulation model of interception loss of snow on forest trees.

A most successful Institute project has been Matching Grant Project B-006-IDA, conducted jointly by the Departments of Agricultural Economics and Agricultural Engineering, concerned with the relation of pumping lift to economic use of ground water for irrigation. Results from this project are already being used by the State Reclamation Engineer to establish reasonable levels of pumping lift in administration of ground water laws.

During the year, Institute research and activities have resulted in 19 publications and eight theses. One publication, a 600-page two-volume edition, was a Water Inventory of State of Idaho compiled for the Idaho Water Resource Board that has become a very useful reference for consulting engineers and government offices, and has furnished useful information for the framework study of the Pacific Northwest River Basins Commission.

A special effort involving the Institute in public education was a short course conducted in June on the subject of legal aspects and responsibilities for allocation of water resources. This was attended by federal, state, and utility administrators from throughout the Pacific Northwest.

ILLINOIS

Ben B. Ewing, Director

Water Problems of Illinois

Like most humid states, Illinois has more problems in providing maximum use of available water than in providing adequate water for man's use. Limitation of the Great Lakes diversion makes it mandatory that the state fully develop its water resource for use in metropolitan areas. The growing cities, expanding industries, intensive agriculture, and plethora of small streams interlacing much of the central portion of the state all make pollution control a major problem. Illinois ranks very low among the states in development of water-based recreation. Major needs are water quality improvement, better long range planning, and institutional reorganization. The state has a generalized conceptual plan for meeting these needs; it now needs a detailed project-by-project plan for accomplishing its goals.

Emphasis of Program

Unlike other states, Illinois has the State Water Survey which is highly responsive to the needs of the state. The Water Survey is investigating many of the water problems of the state and is developing a model which can be used for detailed water resources planning. The role of the University of Illinois Water Resources Center is to develop fundamental applied research which will complement the work of the Water Survey and provide new knowledge which will refine the model.

Research is needed on urban hydrology, fate of pollution in small streams, impact of agriculture on water quality, water quality control in the Great Lakes, advanced waste treatment methods, water quality requirements for recreation, application of modern systems approaches to water resources planning, and institutional arrangements for management of water resources.

Each university should exert its research efforts primarily on those research needs which it is well qualified to undertake. The emphasis of the program therefore reflects the subject areas for which Illinois universities have become recognized as "centers of excellence" as well as the research needs of the state. The University of Illinois and the associated state scientific surveys have established expertise in stochastic hydrology, in river morphology, in ground water flow, in plant-water relationships, and in the ecology of small streams. The University of Illinois is world-renowned in systems analysis and this talent is being turned to applications in water resources planning. These six areas of expertise will continue to be encouraged.

Accomplishments

Professor V. T. Chow has begun to apply his theories on stochastic hydrology to water resources planning as a part of an allotment project entitled "Stochastic Analysis of Hydrologic Systems" (A-029-ILL). He is developing practical methods to apply stochastic non-linear mathematical models to actual problems in Illinois river basins.

Mr. John B. Stall is continuing his study of the "Hydraulic Geometry of Streams" (B-023-ILL) which is an extension of his highly successful study of Illinois streams (B-005-ILL) to more general application of these empirical relationships to other streams across the nation. This is an example of extension of the "center of excellence" concept to serve the nation. Professor B. C. Yen is also contributing to the study of river morphology through his study of "Hydraulic Resistance in Alluvial Channels" (A-033-ILL).

Professor E. B. Small is continuing his study of the protozoan ecology of a small stream (B-028-ILL) along with oxygen relationship research on the same stream by Dr. J. H. Austin and Dr. F. W. Sollo under FWPCA sponsorship and aquatic biology studies by Dr. R. W. Larimore. Dr. Larimore is also expanding his studies of the Kaskaskia River (B-025-ILL) and has recently initiated a new project (A-040-ILL) to evaluate the assimilation of municipal waste in a small creek, in the river, and finally in an impoundment. Dr. E. R. Holley is continuing his study of reaeration rates in streams by considering the effect of the presence of oxygen-demanding material in the water on the rate of transfer of oxygen from the atmosphere (A-037-ILL).

Professor N. G. P. Krausz has completed an exhaustive study of "Intergovernmental Relationships in the Administration of Water Resources" (B-009-ILL). His report recommends legislation to improve administrative and institutional structure and has been well received by water resources agencies throughout the country. Professor W. L. Keith is appraising flood plain regulations in five states (A-030-ILL). Dr. D. D. Baumann of Southern Illinois University is studying the economic and social impact of snow in urban areas (B-032-ILL).

Professor V. T. Chow is well launched in his study of "Advanced Methodologies for Water Resources Planning" (B-030-ILL). He is developing working procedures for applying stochastic dynamic programming to practical water resources planning. Professor E. R. Swanson is applying linear programming techniques to the optimization of water used for irrigation in Illinois agriculture (B-014-ILL). Mr. G. E. Stout and Dr. D. D. Meredith are cooperating in a "Study of the Hydrology for Models of the Great Lakes" under a project supported by the Water Resources Center from state funds. This is the first step in the development of a management model of the Great Lakes which could be a most powerful tool in the long-range planning for this important national resource. Professor Hinomoto is starting an operations research study to optimize capacity expansion for water supply systems. Mr. W. B. Betchart, who has been broadly educated in water resources problems while working for two years as an administrative assistant in the Water Resources Center, is now commencing a systems analysis approach to the rational design of water quality surveillance programs.

INDIANA

Daniel Wiersma, Director

Current and Anticipated Water Problems For the State

Management of the quality and quantity of water is the primary water resource problem for Indiana. Water quality is of paramount concern. The quality of runoff waters from both rural and urban areas should receive special attention. The effect of degradation in natural lakes, rivers, streams and reservoir waters on aquatic life, aesthetic and recreational values and the various water supply user groups is of interest to everyone.

Flooding along the major streams and rivers is a constant hazard. The planning for and construction of structural works is in continual progress. Nonstructural considerations for flood control have not received their proper attention.

Only in small isolated areas is there a deficiency of both surface and ground water for domestic purposes. Further investigations are needed on ground water reserves. The integration of the use of both ground water and surface water is considered advisable. In the long run, more development for water supply will become necessary.

Indiana is in the process of formulating a State Water Plan. They are also involved in four Type I Basin studies, and one Type II study. The State has as an objective the development of its water resources for the most beneficial good to its people.

Research Program for the Center

Planning for the development of water resources requires information relative to runoff occurring from the various watersheds. Stream gaging networks are inadequate to provide all the essential data. Results from Projects B-003-IND and B-016-IND will facilitate making estimates on small ungaged agricultural watersheds, while from A-001-IND and B-008-IND a hydrologic atlas with computer programs will be available for watersheds up to 300 square miles. Projects B-002-IND and B-022-IND concern the effects of urbanization on runoff characteristics of a watershed. Water quality of the urban runoff will also be considered.

The ground water surface of an aquifer can be graphically represented by a computer program developed by Project A-006-IND. The procedure uses the same basic data as the analog model, but is much less expensive to construct.

Studies concerning water quality will continue to receive major emphasis. Project A-005-IND has studied the persistence of pesticides applied in a watershed. The soil characteristics of a watershed and their influence on sedimentation of reservoirs is the objective of Project B-013-IND. Further work will be initiated on the quality of rural runoff. The economic analysis of water quality control systems will be studied under Project B-020-IND.

New emphasis will be placed on interdisciplinary research. A systems analysis of a sub-region of the Wabash River Basin will be made under Projects A-012-IND, A-013-IND, and A-014-IND.

Direct Application of Research Findings

The Dean of Agriculture, Dr. R. L. Kohls, reported some of the results from Project A-005-IND to a five state Governors Conference considering the use of pesticides in the Lake Michigan area. In essence he stated that the insecticides phorate and carbaryl applied in a watershed did not persist at a level high enough to affect the highly sensitive test organisms.

In Indiana critical shortages of manpower in the water resources related occupations are the findings reported by Project A-008-IND. As a result, a new associate degree curriculum has been developed for the training of technicians. This program has the acceptance of industry and others interested in the hiring of such personnel.

Other Activities and Accomplishments

Public involvement by the Center includes such activities as the State Water Resources Legislative Study Committee, State Water Plan, Interuniversity Council for the Wabash Basin, Wabash Valley Interstate Commission, Wabash Valley Coordinating Study Committee, and the Great Lakes Basin Comprehensive Study.

A series of water resources seminars featuring several outstanding men in system analysis has resulted in the introduction of a new academic course to be offered this coming year. Four other new courses related to water resources will also be offered.

Short courses related to water quality or water utilization are offered annually in the Civil Engineering Department. Liaison is maintained with the Cooperative Extension Service Specialist's Committees which relate to the water resources.

Administrative problems include providing Non-Federal money for matching grant projects, involvement of social and behavioral scientists in the program, the organization of interdisciplinary research, and the participation by other Universities.

The Center has not supported any regional research. Members from the Center have been active in proposals involving the Argonne Universities Association, the Committee on Institutional Cooperation, the Great Lakes Basin Commission and the Wabash Valley Interstate Commission.

IOWA

Don Kirkham, Director

In Iowa, as well as in the Nation, there is growing concern about pollution of streams, lakes, and reservoirs by agricultural fertilizers coming from agricultural lands. Agricultural fertilizers reach the streams, lakes, and reservoirs on an areal basis, not as a point source, and therefore they can not be incorporated into a point source treatment facility. The following figures give a global view of the seriousness of the problem, both in the U.S.A. and in Iowa. During the period 1955 to 1965, nitrogen use in the U.S.A. increased from less than 2 million tons to 4.3 million tons; phosphorus use increased from 2.3 million tons of P_2O_5 to 3.4 million tons of P_2O_5. It is estimated that by 1970, the industry will have a capacity for processing about 10 million tons of P_2O_5 annually. In Iowa, about 100,000 tons of nitrogen were used in 1960 as compared to 540,000 tons in 1967. Phosphate fertilizer used in Iowa increased from 115,000 tons in 1960 to 350,000 tons in 1967.

Recognizing the need for interdisciplinary basic and applied research in the area of agricultural pollution, Iowa State Water Resources Research Institute with other institutes in the region initiated the action for a conference entitled, "Clean Water for Agriculture". The conference is scheduled for November 18-20, 1969. It will be held at Iowa State University, Ames, Iowa, with the cooperation of mid-continent state water resources research institutes, and the Iowa Agriculture and Home Economics Experiment Station. The Federal Water Pollution Control Administration is also cooperating. The Iowa State University Extension Service has served a major role in planning the conference as has the University of Missouri Water Resources Research Center. The main purpose of the conference is to determine the status of knowledge relating to agricultural pollution of surface and ground waters.

During F.Y. 1969 there were 18 allotment and 5 matching grant research projects, all of which were either fully or partly financed by OWRR funds, under Public Law 88-379. The following projects have been completed as of June 30, 1969, and completion reports are being prepared: A-001-IA: Dougal; A-013-IA: Willrich; A-014-IA: Ruhe; A-017-IA: Bachmann; A-018-IA: Barnard; and A-022-IA: Dague. In addition, the following projects will be completed during the calendar year 1969: A-024-IA: Johnson; B-005-IA: Johnson and Hines; and B-002-IA: Kirkham. The above projects resulted in 25 technical publications,9 M.S. theses, and 2 Ph.D. theses. The members of the Institute Council gave 4 talks on State, National and International meetings, and served as panel members in State and National meetings. The Institute also sponsored three seminars on various subjects related to Water Resources. Nine new courses were introduced at Iowa State University and 13 new courses were introduced at the University of Iowa.

KANSAS

William L. Powers, Acting Director

As evidenced by the nature of our research projects, current and anticipated water problems for Kansas fall mostly into two categories; the water cycle and water quality.

Potential pollution from agriculture is one of our most serious problems. The cattle feeding industry in Kansas is expected to increase greatly in the next few years which will, in turn, increase the danger of pollution from feedlot runoff. The increased use of pesticides for the control of insects and weeds adds more chemicals to the soil and air which may eventually find their way into our streams and groundwater aquifers. Ever increasing use of chemical fertilizers containing nitrates, chlorides, and sulfates increases the possibility of groundwater contamination. Disposal and treatment of wastes from municipal and urban fringe areas also continues to be a problem.

We have had several projects designed to characterize and eliminate these problems. Research from project A-008-KAN showed that the quality of feedlot runoff was quite variable and was greatly influenced by temperature and rainfall rate, but relatively unimportant were the manure thickness and frequency of lot cleaning. Further research on the feedlot problem is being done under projects A-015-KAN, A-029-KAN, and A-026-KAN which plan research on treatment techniques and pollution effects on wildlife. Projects A-016-KAN and B-007-KAN are designed to study nitrate and pesticide movement in soils. Results from the completed project A-016-KAN show accumulation of nitrate in soils under feedlots and areas where large amounts of nitrate fertilizers have been added. Urban and municipal water quality problems are being studied under projects A-030-KAN,A-031-KAN, A-028-KAN and B-015-KAN which deal primarily with water treatment and quality prediction.

Research on the water cycle has been centered around water movement in porous media, water recharge and water loss by evapotranspiration. Mathematical computer models have been developed for water flow from research on projects A-018-KAN and B-011-KAN. Further research on such models will be done in project B-018-KAN which will include the evapotranspiration process. We presently have three projects A-005-KAN, B-010-KAN and A-022-KAN for studying water use by plants. The first two of these are aimed at reducing water loss from evapotranspiration. Project A-021-KAN is directed toward finding a means of recharinging ground-water supplies by putting extra irrigation water from furrows in a pit to sup back into the soil and back to the groundwater. Results from computer models are now being used to predict water movement as in recharge experiments.

Some of the other activities and accomplishments involved regional conferences. A project leader and his student attended the Evapotranspiration Conference at Lincoln, Nebraska planned during the regional institute directors' meeting last year. Plans are being finalized for a seminar at Ames, Iowa on "The Role of Agriculture in Clean Water." In addition, the directors of several regional institutes contributed to a seminar on "Modifying the Soil and Water Environment for Approaching the Agricultural Potential of the Great Plains." Also, the Director of the Kansas Water Resources Research Institute (KWRRI) has close liaison with the Water Resources Board of Kansas. The director has talked with the Kansas Irrigation and Reclamation Association on evapotranspiration and has conferred with the Riley County Commissioners on problems of waste disposal in the Tuttle Creek area.

The director of KWRRI has been instrumental in the development of new microclimatology courses at Kansas State University. He has also helped to organize and select the staff for a new Evapotranspiration Laboratory.

As indicated above, we feel that KWRRI has taken an active role in water resources research and planning both on a local and regional level. We all feel that Public Law 88-379 is of great benefit to Kansas and the surrounding region.

KENTUCKY

Robert A. Lauderdale, Director

Aside from problems of flood protection and problems arising from surface mining operations, Kentucky's problems, as well as her greatest opportunities, lie in planning the development and conservation of its water resources. One of the state's most pressing problems is how to alleviate the poverty which persists in much of the state. With proper development and management it may be possible to use water as one of the tools to upgrade the economic and social conditions of these regions.

Roughly one-half of the Institute's projects are concerned with the economic and social benefits to be derived from water resources development. Project A-006-KY (L. D. James), entitled "The Economic Impact of Flood Control Reservoirs", has multiple objectives which include the effects of large reservoirs on local employment patterns, changes in land use, economic losses from the innundation of valuable land, and income redistribution resulting from the reservoir. The final report will attempt to provide answers to such questions as what economic benefit results from reservoir recreation, what value should be placed on the hardships imposed on people who lose their property, how can reservoirs be operated to produce more benefits, and how effective are water projects in helping low income families to improve their position. Project B-015-KY, "Measuring the Intangible Values of Natural Streams", will continue and expand on the work of A-010-KY. It complements some of the work being done in project A-006-KY. The major emphasis is on the esthetic and recreational value of streams. The project should be of value to the Kentucky Commission on Wild Rivers as well as to others who have jurisdiction over the preservation and conservation of recreational areas.

Two projects, A-020-KY and A-022-KY are concerned with the problems imposed on people because of forced migration and on the cultural changes resulting from water resources development. Since a major part of the work is to be done during May and June, the results are not yet clear. However, it is important that the long term effects of reservoir development on the people most affected be considered, and these studies should provide the kinds of information needed to do this. The long range results should be the development of improved techniques of evaluation and planning to insure that this group of people will not suffer as the result of being forced to relocate.

Two projects concerned with the growth of algae have economic significance to the state, since algae growths are a potential problem in lakes which have been created for recreational and other uses which require water of high quality. A-018-KY is a study of inhibitory compounds produced by algae, with one of the objectives being to identify the chemical nature and action sites of these compounds. With this information it may be possible to synthesize similar compounds which could be used to help control algae in water supplies or recreational reservoirs. Project A-022-KY is concerned primarily with the re-cycling of nutrients through the decomposition of dead algae cells, a process which is responsible in part for the recurring blooms which plague many lakes. A somewhat related, but much broader project is B-005-KY, an ecological study of a water to be impounded. The objective of the project is to develop a predictive model which can be used to forecast the changes in quality which may be anticipated after a water is impounded.

The Institute has continued its efforts to expand its program beyond the University of Kentucky campus. This past year all of the universities offering graduate programs were invited to submit proposals for research. Although none were submitted for FY 1970, some response is expected for FY 1971, particularly in the areas of ecology and economics. The Institute sponsored two seminars for the Kentucky Water Resources Council, at which the results of Institute projects were discussed. The chief benefit from these talks has been to establish a closer relationship between state and federal agencies and the Institute. By presenting the work of the Institute to the council, it is hoped that the interaction between the state and the Institute can be enhanced, and that the Institute will be better able to assist in solving the state's problems.

The types of research which are supported by the state institute do not often lead to results with immediate and definable application. The demand for Institute reports, however, indicate that the results of our projects are being studied and perhaps used by a large number of agencies. The benefits from OWRR projects will be cumulative and should not be expected to apply to a specific local problem unless the project was designed to be restricted to a single application from its inception.

No significant problems have been encountered in the administration of the Institute program. However, projects in engineering and the physical or natural sciences have been particularly hard-hit by the Selective Service, and no relief is apparent for FY 1970. No significant changes have been made in the composition of Institute's committees or in the level of support provided by the state.

LOUISIANA

Elvin J. Dantin, Director

The principal research projects funded by the Louisiana Institute possess clearly defined objectives in the field of water resources development. These objectives, if attained, will be of practical value to the citizens of Louisiana and to people living under similar hydrologic and hydrogeologic circumstances.

A number of the Institute's projects, while planned for their relevance to the citizens of Louisiana, reach far beyond the state's confines. One such project deals with the storage of fresh water in saline aquifers.

Fresh Water Storage in Saline Aquifers

In 1965, one of the first projects proposed to the LWRRI was a laboratory study, to be supplemented and expanded by development of a model for digital simulation, of the storage of fresh water in an aquifer containing brine. The fresh water would be injected so as to displace the connate water of the formation. The study, by Dr. Oscar K. Kimbler (A-002-LA) proposed to alleviate a situation encountered by the inhabitants of low-lying, swampy coastal areas: the construction of a reliable, year-round, water supply. In such areas, the surface water resources become brackish or salty in the low-flow period of the streams, and the underlying water-bearing formations contain brine instead of potable water. Because of this, it is believed that the coastal areas have never reached their full development potential either as industrial or recreational areas. Such circumstances exist throughout the Gulf Coast of Louisiana. The immediate application of preliminary results of the study for the town of Empire, Louisiana shows the relevance of the investigation.

In FY 1969, Dr. Kimbler's study was extended (A-011-LA) to cover the effect of dip on the efficiency of the cyclic process of injection, storage, and offtake. Although the attempt to incorporate dip in the model proved to be far more difficult than anticipated, some progress was made in FY 1969 in overcoming the obstacles.

Manpower for Research

A project completed in FY 1969 that may influence events far beyond the boundaries of Louisiana is a study of the availability of manpower for water resources research (A-015-LA). Dr. James E. Lewis, who made the study and supports his thesis with numerous analytical statistical tables, contends that the outlook for manpower is not bright because of the limited supply of people with the requisite interests and abilities to do research and the intense competition for precisely this type of personnel.

Amelioration of Subsurface Salt Water Encroachment in Baton Rouge

The Baton Rouge multidisciplinary project (A-001-LA, A-004-LA, B-001-LA, B-002-LA, B-003-LA, B-004-LA, and B-005-LA) shows that the encroachment of salt water in the aquifers underlying Baton Rouge can be stopped by the construction and operation of two strategically placed scavenger wells to pump saline water to waste. Another result of the study was the analysis by Professor R. G. Kazmann of USC and Geological Survey data on the 1964 levelling, which showed that the land surface in Baton Rouge is subsiding; the implication is that the net offtake from the aquifers must be reduced if Houston's experience with land surface movement is to be avoided.

An outstanding dissertation scheduled for Bulletin publication is "Economic Aspects of Ground-Water Basin Control," by L. H. Falk (B-005-LA), which has furnished a procedure for evaluating a recharge project and rationally determining how and when the costs should be paid. Although the work is the basis for the economic studies of the Baton Rouge multidisciplinary project, it is expected to influence the thinking of leaders in many areas faced with the management of ground-water basins. A portion of the study is devoted to a detailed, concrete analysis of the Los Angeles situation, a recharge project now operating.

As a direct result of the Baton Rouge project, Professor William A. Wintz, Jr. (A-020-LA) has started to run first order levels through the area of subsidence and to attempt to correlate changes in land surface elevation with changes in water level in the several water-bearing formations. The results of this will help determine the pace at which importation of additional water to the Baton Rouge area should occur.

Anti-Pollution

Two projects of interest to the citizens of Louisiana concern pollution. One (A-019-LA) is a study of the efficacy of pollution abatement efforts in the Lake Pontchartrain area by Dr. Daniel Stern of LSUNO. The other, by Professors Charles W. Wilson and F. E. Beckett of Louisiana Polytechnic Institute, would decrease river pollution by utilizing paper mill waste for the irrigation of hardwood. An offshoot of this project and its predecessor (A-009-LA) was a successful symposium on the use of effluent from municipal sewage plants for the dual purpose of abating pollution and irrigating crops, held in Ruston, Louisiana, in July, 1968.

The Institute published, though did not sponsor, an edited version of a dissertation by Dr. Paul H. Jones which presented a new and original synthesis concerning the occurrence of fresh water at depth and the genesis of brines and geopressure zones in the deeper sediments of the Gulf Coast. Three additional theses resulting from research sponsored by the Institute (A-004-LA, B-004-LA, A-007-LA, and A-009-LA) were completed during FY 1969.

In sum, the now well-established Louisiana Water Resources Research Institute has an overall balance sheet weighted heavily on the successful side. In the future, as in the past, projects will be selected for their relevance and potential usefulness.

MAINE

Edgar A. Imhoff, Director

Water Problems of Maine

It is the policy of the Center to seek declaration of new problems and redefinition of "old" problems on a somewhat continuing basis. Thereby, relevant research topics are uncovered and progress is scaled against work to be accomplished.

The multi-interest Advisory Committee of the Center focused on water problems in its annual meeting. In addition, problem-discussion interviews were held with technical personnel of twelve agencies, four universities and three private organizations. Thirty-six seemingly valid water problems were cited. One-half of the cited problems were related to water quality management and protection, FCST V. One-fourth of the problems were related to water resources planning, FCST VI.

Comments solicited by the Center reflect a majority opinion that Maine's greatest water problem is the actual and potential deterioration of the quality of the water environments. Many knowledgeable individuals are concerned especially with restoring or preserving the quality of Maine's 2,500 freshwater lakes. Research in water resources planning is of great urgency in Maine because of socio-economic factors which seem to dictate a need for the accommodation of economic growth--a growth that probably will include heavy metal mining, petroleum refining, thermal and nuclear power development, and increased production of pulp and paper products.

Thrust and Relevance of the Center Program

An adopted policy of the Center's Executive Committee, urging environmental quality studies, is reflected in the fact that all but one of the ongoing and proposed research projects are concerned with water quality. The biological effects of pollution in estuaries is being investigated in A-011-ME. Dr. David Dean, Director of the Ira C. Darling Center states that project results will be valuable in predicting biotic changes resulting from increased or decreased pollution loads. Dr. Otis Sproul's inquiry into adsorption of viruses on mineral surfaces, A-013-ME, promises to reveal data which will support the design of improved soil adsorption systems. Four ongoing and scheduled projects focus on lake water quality. Dr. Wayne Hall is leading an investigation (A-014-ME) which has demonstrated to date that septic tank systems do not effect significant removal of nutrient substances, and--in fact, may encourage eutrophication by the conversion of insoluble forms of N and P to soluble forms. This study will contribute useful data to planners and water poltuion control authorities. In May, 1969, a companion study (A-015-ME) by Dr. Hall was initiated to explore the causes, effects and control of eutrophication on several case-study lakes, with the objective of providing to engineers and planners information which will be highly useful in designing land use controls, water control facilities and remedial legislation. A new study (A-016-ME) by Dr. Lotse, should be of great significance in clarifying the effect on the eutrophication process of retention of phosphorus in lake sediments. Dr. Stephen Norton will lead a new inquiry (A-017-ME) which will have practical implications in the prevention or management of algae problems of lakes. Improved techniques in the modeling of physico-chemical water quality conditions in a tidal river has resulted from an investigation (B-003-ME) led by Dr. Edward Bobalek.

State Highway officials have responded affirmatively to results of project A-007-ME which indicate a substantial build-up of sodium in roadside soils and chlorides in some roadside wells as a result of salt applications for de-icing. Further inquiry by the principal investigator, Dr. Fred Hutchinson, is being supported by Federal Highway funds.

Other Activities and Accomplishments

Although the efficient execution of problem-related research is the major contribution to be made by Center programs, we are very much concerned with disseminating research results in a manner enhancing public education. Accordingly, in FY 1969, we (1) initiated a newsletter having a circulation of 300, (2) addressed several service groups, (3) cut a radio tape on water problems, (4) accepted study responsibilities on the Governor's Task Force on Environment, (5) convened a special technical committee to study the problems of the Penobscot River Basin, with the objective of energizing an engineering planning study, and (6) designed a seminar to bring private consultants, state agencies and research together for a beneficial exchange on the subject of the Research-Planning Interface.

Regional cooperation is particularly important to Maine which--although somewhat isolated geographically--faces many problems common also to the more developed portion of New England. Accordingly, the Center has participated in the planning of a national conference on Ecological Considerations in Water Resources to be held in Boston on Nov. 4-5 under the sponsorship of the New England Council of Water Center Directors and the New England River Basins Commission. Additionally the Center attended a meeting of the Directors of the Northeast States Centers at which research and planning programs of Federal agencies were presented. We find the maintenance of communication with other Center Directors of great value in stimulating and improving our own research.

MARYLAND

R. L. Green, Coordinator

The regional climate generally favors Maryland with respect to available water resources. However, from even casual study of the concentration of population, it is obvious that major problems relate to quality, spatial distribution and institutional arrangements for management of water resources. In 1960, 80 percent of the State's 3,100,000 people lived in the METRO MARYLAND area encompassed by the Annapolis-Baltimore-Washington triangle; all projections point to further demographic imbalance. Simultaneously, with its direct needs for water, this population plus that of the nearby Eastern Seaboard has time, money and desire for water-based recreation. The quality of water for fisheries and recreation, the need of channels and harbors for shipping, the need for water for industrial uses (especially cooling) and the use of streams and bays for effluent disposal summarize the diversity and conflicts in needs, uses and vested interests.

Since inception of the Center's program in May 1965, the primary research effort has been related to water quality. Some research has been directed at water resources systems including analog simulation, hydrology and recreational uses. The last project initiated in FY69 is related to private and public interests and management systems. A matching fund project has been approved to initiate an economic study in FY70.

It is the Center's concept that annual allotment funds and, to a lesser degree, matching funds should be considered as "seed money." In two instances to date, this has been completely successful; work initiated under Projects B-001 and B-002 pertaining to enhancement of recreational uses of the Chesapeake Bay through study of sea nettles contributed data for Congressional hearings leading to direct appropriations for Sea Nettle Research; similarly, work initiated under A-004 pertaining to disposal of swine wastes, although producing inconclusive results, provided guidelines for a more comprehensive project funded by FWPCA and the Maryland Agricultural Experiment Station.

The outstanding example of immediate applicability of research continues to be from Project A-002, concerned with effects of thermal loading on an estuary. Rather large scale field studies with State financial support were in progress by the University's Natural Resources Institute when the Center was organized. Center funding enabled complementary laboratory studies. Data from field and laboratory were useful to the Maryland Water Resources Department and Commission in adopting Water Quality Standards in 1967. Experimental procedures provided data on the effect of exposure of aquatic organisms to elevated temperatures for 24 hours. When an appropriation permit application to the Department of Water Resources for a new power plant indicated elevated temperatures for very short periods of time, a new series of laboratory ecology studies of shorter exposure were initiated.

The Center sponsored two public meetings in FY69. At the first, Maryland Water Resource Research Needs, representatives of State and Federal agencies concerned with water resources discussed "Needs" from their respective viewpoints. The second meeting was the Fourth Annual Program Review at which progress reports were given by investigation leaders to an audience of faculty, students and agency representatives.

The Center became a co-sponsor with NSF in the support of a Thermal Workshop at Solomons, Maryland, November 3-7, 1968. This Workshop was attended by approximately 200 scientists and engineers from about 20 states and seven other countries. It was recognized as a United States contribution to the International Biological Program.

During FY69, a graduate program in Agricultural Engineering was approved offering another opportunity for advanced graduate study and research in a discipline concerned with water resources. Included in this program is the opportunity to do research in aquacultural engineering and what is believed to be the first formal course in this subject is scheduled in the Spring Semester 1970. The interchange of knowledge, concepts and ideas between faculty members from its interdisciplinary program greatly facilitated development of the substance and need for this new subject matter area. The first research project under this program, funded by the Maryland Department of Chesapeake Bay Affairs and the Bureau of Commercial Fisheries, USDI, is a study of applications of engineering in the harvesting and processing of oysters.

During FY69, 12 faculty members were active as investigation leaders assisted by 14 graduate research assistants. One (A-002) graduate student in Zoology received his Ph.D. degree and one (A-009) in Microbiology received her M.S. degree. Since 1965, a total of 24 faculty members have been investigation leaders and 23 graduate assistants have received support from Center projects.

Liaison with State and Federal agencies has been maintained through meetings previously cited, by faculty participation in the Governor's Conference on the Chesapeake Bay in September 1968, the Annapolis Hearing of the National Estuarine Pollution Study where Dr. L. Eugene Cronin was a member of the Expert Panel; Dr. John H. Cumberland of the Interdisciplinary Advisory Committee volunteered a prepared statement; Dr. Gordon M. Cairns spoke for the State Soil Conservation Committee; and Dr. R. L. Green spoke of University-wide interests and viewpoints.

In addition to my University duties as Coordinator of the Water Resources Research Center and Head of the Department of Agricultural Engineering, I have been a member of the Maryland Water Resources Commission and have attended its monthly meetings since 1964. In December 1968, I was appointed by Governor Agnew as Chairman of a nine-man Water Sciences Advisory Board whose function is to consult with and advise agencies concerned with pollution abatement. The frequent contacts with State natural resource agency personnel facilitates coordination and information exchange.

MASSACHUSETTS

Warren Litsky, Acting Director

Five major problems currently concern and will continue to concern the State of Massachusetts:

1. Protection and prudent use of lakes.
2. Protection and prudent use of major streams flowing through metropolitan areas.
3. Improvement of methods for planning optimum use of small independent watersheds.
4. Cleansing and protection of estuaries.
5. Protection of valuable wetlands.

The following research being conducted by this Center is directed to the above-described needs:

Arrest of Eutrophication

Project B-005-MASS seeks to find ways to eliminate bottom deposits in lakes as a major factor in lake pollution and eutrophication. Project B-006-MASS is directed to the possibility that controlled intervention into lake microbial processes may suggest practicable ways to arrest the formation of troublesome algal blooms. Project A-023-MASS seeks to determine whether rooted aquatic plants may be useful in trapping nutrient materials in the lake. Project A-018-MASS is concerned with the development of practical ways of utilizing special ion-exchange resins to remove excessive plant nutrients in the lake water.

Stream Resource Planning

Project B-011-MASS is directed to the development of methods for planning and designing metropolitan area water pollution control systems. Project B-003-MASS is directed to an examination of the attitudes of decision-makers in respect to water rights conflicts as a basis for clarifying the processes by which water resource management institutions are evolved. Project B-015-MASS represents an examination of the historic interactions of an urban river and the culture of the population residing on its watershed as a basis for improved understanding of deep-rooted attitudes and traditions affecting the decision-making process.

Protection of Wetlands

Project B-010-MASS is directed to a study of the impact of highway construction on wetlands impairment or formation with the objective of (1) developing procedures for controlling adverse effects, and (2) recommending ways in which the affected wetland, or a newly formed wetland, may be so structured and managed as to represent a regional resource. Project B-012-MASS seeks first to characterize the wetlands of Massachusetts, second to identify and interrelate the important factors influencing wetlands preservation, and third, based on this knowledge, to evolve a practicable system for management of wetlands.

Planning Optimum Use of Small, Independent Watersheds

Project B-004-MASS represents a study of alternative water uses and management practices and seeks to develop a general model for determining that combination of water uses and management practices that will produce the greatest economic benefit to the watershed.

Several projects provide knowledge applicable to all problem areas. Project B-008-MASS seeks to establish an improved technique for determining and predicting watershed response to hydrologic influences. Project A-024-MASS is analyzing discontinuities in regional population projections as a basis for evolving an improved technique for making such projections in an uncertain future.

Beneficial results do no necessarily await the completion of the research project. For example, Project B-008-MASS has already produced more reliable information than had hitherto been available to consulting engineers and planners concerned with the hydrology of Massachusetts watersheds. In fact, each of the above projects has had some influence in shaping the thinking of water resource planners by drawing these individuals into seminar discussions and related research. Project B-003-MASS has had an interesting influence in stimulating water works operators in Massachusetts to think about existing or probable water rights conflicts. This project, which utilized a questionnaire in its early stages, reached every water works operator in the State, and it has had an excellent response. Project A-001-MASS has been of use to planners by throwing cold water on the idea that farm ponds could serve as recreational waters. This project has had an important secondary effect in that it is providing the Center with the basis for a classification of all lakes and ponds in Massachusetts which will, we believe, represent the most complete and valuable data base for lakes yet developed in this area. Project A-022-MASS, a short intensive study of attitudes of decision-makers in the Springfield metropolitan area in regard to water pollution control, evoked a great deal of interest. It appeared to impress the news media in this area with the significance of the diverse and often hidden factors that go into shaping important attitudes and traditions. Project A-019-MASS demonstrated with some impact the hazard of using chlorinated hydrocarbon pesticides on land where drainage or wind could carry this toxic material to breeding areas of valuable marine aquatic forms. Project A-005-MASS provided a technique for water conservation that is adaptable to efficient use of water in harvesting of cranberries. This technique is now being used in cranberry producing areas of Cape Cod.

The Acting Director of the Center has met with the Water Resources Commission at its monthly meetings to maintain a continuing liaison between that official agency and the Water Resources Research Center. Principal investigators have contributed widely to public understanding through participation in conferences and seminars, and through public talks. However, while the Center's program has been expanding, it like most University components, has been adversely affected by recent action of the State legislature in respect to appropriations.

The Center has continued to participate in the work of the New England Council of Water Center Directors and currently is involved in a joint effort to develop an administrative framework in which regional research may be most effectively conducted.

The Center has established a policy of seeking to strengthen the activities of water resources research in other educational institutions of Massachusetts and in line with this desire, it has established joint projects with Springfield College (Surface Waters of a Small City); Smith College (A Study of Vascular Plant Flora in a Small River and its Floodplain); Northeastern University (Estuarial Studies). It is hoped that through a system of inter-University cooperation within Massachusetts, educational and research programs will be jointly strengthened and enhanced.

MICHIGAN

Robert C. Ball, Director

The State of Michigan is unique in that nearly 35 percent of all the fresh water of the United States occurs within its boundaries. Michigan's 11,000 lakes and 35,000 miles of streams constitute a vast economic and recreational resource of national importance. Our problems are not primarily of quantity of water available to meet demands; rather, they are concerned with strict attention to the maintenance of high levels of water quality in the many internal and peripheral waters.

Since almost all of Michigan's rivers arise within the state and empty into the Great Lakes, all the nutrients, sediments, and other pollutants put into the streams eventually reach one of these important bodies of water. The disastrous results of pollution in Lake Erie are well documented. It is estimated that the turnover time of water in Lake Michigan may be as long as 100 years, thus, the threat of pollution to the lake is even greater and of more urgent concern.

The Institute's Advisory Committee recommends strong consideration of projects concerning nutrient input into the lakes and its relation to eutrophication. This decision is reflected in both the past year's projects and those for the forthcoming period. We believe these studies will contribute to the effort to solve the problems of environmental contamination and degradation.

During the past year the Institute has funded several projects with direct bearing on this problem. These include an in-depth look at the bacterial and viral aspects of water quality through Projects A-026 and A-027. The Michigan Institute supports studies of the movement of nutrients from land and the streams into Lake Michigan under Projects A-022 and A-023. From these come data showing that the streams entering Lake Michigan from Michigan's lower peninsula contribute over 11,000 pounds of phosphorus per day. These data contributed to the decision by the state regulatory agency to require 80 percent removal of phosphorus from sewage effluent by municipalities in the Lake Michigan drainage basin by 1972.

Strongly related to environmental contamination is the critical problem of pesticide pollution of Lake Michigan. Pesticides underwent biological magnification in the lake resulting in vast salmon stocks being declared unfit for processing as human food. This year alone, this situation will result in a multimillion dollar economic disruption and the loss of a vital commercial and recreational resource. Anticipating such a problem, we funded two research projects, A-012 and A-029, having a direct bearing on environmental pollution by pesticides. Both have been productive projects and A-012 has resulted in the development of a procedure of using living freshwater mussels as an in situ bioassay for pesticides that will probably become a standard procedure for the interstate surveillance of waters flowing to Lake Michigan.

Singly, and in cooperation with other agencies, we have sponsored basic ecological studies on the interactions of environmental stress on streams and lakes (A-023, A-030, and A-031) which will, as they progress, develop a store of basic knowledge that can be translated into action programs.

The importance of water resources in heavily urbanized areas is reflected in our funding of a study of the bedrock delineation of groundwater resources in the Detroit metropolitan area, Project A-011.

Our staff continues to be actively involved in both public and academic educational programs reflecting the Institute's commitment to help inform the public in the area of water resources. To indicate the scope of the direct citizen educational aspect of this function, Institute personnel gave 30 speeches to such diverse groups as the Junior Chamber of Commerce, the Lions Club, and the Audubon Society. In addition, many individual laymen and professionals have received a wide variety of water resource information in response to their personal inquiries. More formally, the Institute cosponsored a two-day, state-wide Conference on Waste Stabilization Lagoons in cooperation with the Michigan Department of Public Health. Cooperation on a regional level has been on an ad hoc basis. For example, by invitation, Institute personnel participated in the workshop on system analysis of the Great Lakes that was sponsored by the Great Lakes Basin Commission.

The Michigan Institute of Water Research continually serves as an example of the seed-grant philosophy used in the funding of OWRR grants. The fact that the Institute is a part of Michigan State University results in its support by university funds at a level that exceeds, considerably, the total support from the Allotment Grant. Because of these bases of support, the Institute now serves as a focal point for research funding of water resource projects by municipalities, chemical industry, watershed groups and others in addition to OWRR sources. An important new, industry-sponsored project is a long-term study of the effects of thermal pollution from both fossil fuel and nuclear-powered electric generating plants. This contract probably will be extended to include a study of radionuclide contamination of receiving waters. All non-OWRR funds, handled directly through the Institute, are now at the level of $250,000 per year and we believe we have now developed a staff, facilities, and contact base that will enable us to extend this to a much higher level.

MINNESOTA

William P. Walton, Director

Past development and management practices in Minnesota, as substantial as they are, have not kept pace with the steadily growing demands placed upon water and related land resources. With the prospect that within 50 years water and related land resources demands and needs may approach or exceed the availability of resources and existing facilities in some areas, the State cannot expect to continue to avert critical problems without an acceleration in resource development and management. Minnesota, with proper development and management has sufficient water and related land resources to satisfy future demands.

The Center's program in FY 1969 was directed toward: establishing a practical baseline of water quality for Lake Superior through use of the continuous plankton recorder technique (A-011-MINN); analysis of existing legislation to determine means for improving water laws in Minnesota (A-015-MINN); ascertaining the physiological and ecological requirements of the algae responsible for severe blooms on lakes (A-016-MINN); determining methods for rainfall-runoff predictions on ungaged small watersheds (A-017-MINN); reconciling water quality management with ecological and social-economic objectives (A-018-MINN); formulation of an optimizing model for water quality on selected stretches of the Upper Mississippi River (A-019-MINN); analysis of hydrologic programs for determination of design floods and for design of spillways and related structures (A-020-MINN); investigation of soil dynamic changes to assist in solving water problems (B-005-MINN); determination of runoff-time distribution for a variety of watershed sizes and slopes (B-007-MINN); determining the role of bottom sediments in the phosphorus cycle for lakes of different types (B-009-MINN); development of techniques where algacides might be used to control pollution in reaches of the Upper Mississippi River (B-010-MINN); development of a mathematical model to predict the role of surface runoff and groundwater flow in overfertilization of surface waters (B-012-MINN); investigation of mist irrigation in potato crop production (B-013-MINN); and investigation of soil moisture movement and retention (B-015-MINN).

The Center's program during the next five years is likely to be directed towards: evaluating water resources administration in Minnesota to provide information for legislative action on reorganization of State Water Resources Agencies (A-021-MINN); measurements to assess extent of eutrophication of the west end of Lake Superior (A-022-MINN); investigation of ecology of periphyton in near-shore areas of the west end of Lake Superior(B-020-MINN); study of citizens groups involved at the grass roots to improve water resources environment in four metropolitan areas (B-031-MINN); determination of ecological conditions in the Mississippi River near Monticello, Minnesota,before and after operation of a nuclear power plant (B-032-MINN); simulating alternative strategies in locating and financing water recreation projects in growing and distressed areas; evaluating impact of water quality and other factors in recreational use of water areas; integrated study of littoral vegetation and invertebrate fauna to understand trophic status and effects of pollution lake metabolism; studies on behavior of snow packs; sociological studies on behavior toward water pollution control; devising methods of reduction of irrigation water losses; studies concerning properties of aquifers; determining effects of agricultural practices on quality of surface and groundwaters; study of use of State Lakes; determining effects of urbanization on water resources; and completion of projects ongoing in FY 1969.

Results from projects A-009-MINN on groundwater contribution to streamflow and aquifers, A-001-MINN on effect of pothole drainage upon groundwater resources, and B-002-MINN on effect of natural sealing potholes have assisted agencies in preparing regional and statewide water resources plans. Information from projects A-007-MINN on use of planktonic desmids as indicators of quality of lakes, A-008-MINN on water quality and organic productivity of lakes, A-011-MINN on abundance of net plankton as an index of eutrophication in Lake Superior, and B-001-MINN on diatoms and zooplankton in Minnesota Lakes has assisted in devising methods to control excessive productivity of polluted lakes; results of projects A-010-MINN on factors affecting aquifer test results and A-014-MINN on recharge from induced streambed infiltration have been used in parts of the U.S. and England to evaluate potential yields of aquifers receiving recharge from streams; the Corps of Engineers has been assisted in development of peak rates of runoff design criteria and flood routing procedures by project A-013-MINN on analysis of runoff from selected watersheds and the Weather Bureau has been assisted in flood forecasting activities by information from B-005-MINN on migration of moisture in the soil induced by winter thermal gradients.

The Center has been helpful in developing 20 new water resources courses, a graduate option in hydrogeology, a program of graduate education in water resources, and recruitment of 21 new faculty members with an active interest in water resources. However, partly because of lack of courses and interest on part of staff in social-economic aspects of water resources, some difficulty has been experienced in obtaining sufficient graduate students in the water resources program.

Members of the Center's Advisory Committee and Consulting Council have participated in water resources planning activities of the State Planning Agency. The Center Director has served as: Minnesota's Water Resources Planning Director (past 2 years) and Governor's representative on Federal-State planning organizations.

Minnesota has provided about $30,000 to the allotment and $49,000 to the matching grant programs in 1968. Management of the Center is vested in an Advisory Committee headed by the Dean of the Graduate School and made up of 15 faculty members. A Consulting Council, composed of 20 representatives from organizations outside the University, counsels with the Center and assists in identifying needed research and providing public liaison.

MISSISSIPPI

Melville S. Priest, Director

All nine projects in the allotment program were completed, as scheduled. The single matching funds project is scheduled for completion within the next fiscal year. From inception of the Institute to the end of FY 1969, the allotment program has included thirty-one projects. All have been completed, and completion reports have been published for all projects other than those completed in FY 1969. It is anticipated that the completion reports on all projects completed in FY 1969 will be published soon after the date of this writing.

The Institute conducted the fourth annual Mississippi Water Resources Conference. The "Proceedings" of the Conference were published and given national distribution. In addition to publications of the Institute, ten technical papers related to the Institute's program were presented and/or published during FY 1969. Several additional papers have been prepared and accepted for presentation and/or publication during FY 1970.

The training of students is an integral part of the Institute's operation. A total of thirty-six students participated in the Institute's federal programs and received payment for services rendered during FY 1969. Of these, fifteen were undergraduate students and twenty-one were graduate students. Many more students in the various areas of the Institute's multidisciplinary programs were intimately aware of its research activities, even though those students had no responsibilities in connection with the research.

The Institute maintains close contact with the fifteen private, state, and federal agencies represented on its Advisory Council. Contacts and cooperative efforts with other agencies are being expanded. For instance, the Pat Harrison Waterway District has agreed to provide matching funds for a study to be conducted during fiscal years 1970 and 1971.

In addition to the federal funds available to the Institute, certain state funds were available for research, development of facilities, and operation of the Institute. Two research projects were supported entirely with state funds. One was completed in FY 1969 and the other is continuing. A new building was assigned to the Institute for development as an hydraulics laboratory. Within this laboratory, a wave basin is now in operation and a recirculating system for the study of free surface phenomena is under construction.

During FY 1970, nine annual allotment projects are being conducted. It is estimated that the individual projects will have been from 35 to 60 percent completed by the end of calendar year 1969. Matching grant projects B-005-MISS and B-006-MISS which deal respectively with organization, development, and management of community water systems in rural areas, and a case study in the formulation of a water resources management plan, are expected to be about 15 to 20 percent completed by the end of December 1969.

MISSOURI

George E. Smith, Director

Missouri citizens have until recent years, given little attention to the state's abundant water resources. Only when excessive runoff causes serious erosion or flooding on the major streams, when July and August precipitation is inadequate for optimum production of summer crops, or in some rural areas where groundwater is highly mineralized and domestic supplies are inadequate, has there been much public concern. Average rainfall is ample for the production of grain and livestock--the main sources of income in the state. There is ample surface water for barge transportation on the major rivers. These rivers also furnish abundant water for the large growing cities and have been used for waste disposal. Changes in work patterns, and more leisure is creating an expanding interest in water for recreation. There is particular interest in utilizing for recreation, but protecting, the clear streams of the Ozark region.

Growing waste disposal problems of the major cities, occasional fish-kills from heavy runoff of large cattle feeding operations or insecticide spillage and concern for eutrophication in ponds and lakes is creating concern about water pollution. There is particular interest in the contribution of agriculture to stream and groundwater pollution, and how control methods will influence agricultural production.

The Water Resources Research Act has given new emphasis to water research at the University of Missouri. It has stimulated public awareness and provided incentives for research that can develop and protect water supplies for future use without the deterioration and problems that have occurred in many of the more populated states.

The four-campus system of the University of Missouri makes it one of the largest of the Land-Grant Institutions in the country. Most disciplines, where water resources research is normally conducted, are included in departments on one or more of the campuses. The demand by the staff for support of water research projects far exceeds available funds. Because of the widespread research interests of capable staff no specific limitations have been placed on the type of allotment research projects funded. There has been a trend, however, to encourage some water studies that have received but limited support in the past. Both basic and applied research is supported. It is expected that the main thrust of the Center's program in the next five years will be in the area of water quality, including research on sources of pollution, techniques that will improve waste water treatment, processes that will permit new mineral discoveries to be developed without pollution of streams in a region where recreational demands for water are increasing, and the contribution of agricultural practices to water pollution.

Some of the early projects initiated with center funds and developed further with other sources of support are becoming useful to the state and region. There is a growing demand for more information than is available. During the past year the individual investigators, a water resource specialist in the Cooperative Extension Service, and the Center Director, have been active in facilitating the practical application of research in the State and Midwest through talks, newspaper and magazine stories, use of radio tapes, and through television appearances.

Some of the more useful findings of Center supported research projects are:

- Natural contents of heavy metals in the clear streams in the Ozark region have been determined. Improved methods for removing heavy metals from water have been developed. Utilization of these new methods will permit development of extensive new lead, zinc and iron deposits without stream pollution. (Projects B-017, B-021, and A-021-MO)

- The addition of heat to multiple purpose reservoirs has increased the growth of fishes and extended the recreation season. With adequate ratios of water volume to heat added by power generating plants there are benefits rather than pollution effects. Acid drainage has not been detrimental when there is sufficient dilution. (Project A-020-MO)

- Techniques have been developed that could increase the capacity and efficiency of existing sewage treatment plants. (Projects A-010 and A-015-MO)

- The Missouri Center, working with other programs on both the Missouri Campus and with other Midwestern states is developing sound information on the contribution of agricultural operations to water pollution. Much of this data refutes many unsubstantiated opinions that are now making headlines. (Projects A-016 and B-037-MO; and regional activities of the Center)

- Supplemental irrigation is a growing practice, in this humid area, to protect the investment input in crop production. Fundamentals involved were developed by Projects A-003 and B-011-MO.

- Studies are being conducted that should serve as a basis for a sound water law in the state. (Project A-008-MO)

- Studies are being made of rural water districts. These districts are bringing ample amounts of pure water to some rural areas for the first time. Major differences in rural and city living are being eliminated. In some areas there is a reversal of movement of people from the country to cities. (Project A-018-MO)

MONTANA

Helmer C. Holje, Director

The research program of the Montana University Joint Water Resources Research Center is now reaching a more productive stage with the completion of four full years of operations. When the program was initiated on April 1, 1965, all of the research projects were new. None of them involved supplemental funding for research projects already under way in other research components of the University System which might have given the impression of productivity at an earlier date. Eleven allotment projects are being closed as of June 30, 1969, and will be producing completion reports and, in most cases, publications during the next six months. Eight new allotment projects are being initiated as of July 1, 1969.

Allotment project A-007-MONT, "Mountain Precipitation and Distribution," provided the basic support for the "spin-off" of a major multidisciplinary research effort involving substantial funding from three other sources. The OWRR funding for A-007-MONT has not exceeded $10,200 in any one fiscal year since the project was initiated on July 1, 1966. The three associated research grants and contracts are as follows:

(1) A contract with the Bureau of Reclamation in the amount of $278,000 for research on the technology of winter cloud seeding was completed on June 30, 1969. A new contract in the amount of $595,000 for continuation of this research has been entered into with the Bureau of Reclamation for the period July 1, 1969, to June 30, 1972.

(2) A grant from the National Science Foundation in the amount of $215,000 for research on the ecological effects of weather modification. This grant expires on December 31, 1969, and a proposal will be made for continuation of the research parallel to the Bureau of Reclamation contract.

(3) A contract with the U. S. Army Research Office--Durham--for research on mountain snowpack as an environmental indicator. This contract will have provided $110,943 in funding during the three-year period July 1, 1968 - June 30, 1971.

A-007-MONT and the above listed projects comprise a major multidisciplinary research program at Montana State University. Coordination has been through a committee representing the Center for Environmental Studies. The completion date for A-007-MONT has been extended for one year to June 30, 1970, so that a more definitive report can be prepared.

The Center has carried on a major research program concerned with the development and application of instrumentation to the measurement of natural factors in remote areas. Completed projects include A-001-MONT, "Basic Hydrologic Studies of Two Selected Montana Watersheds"; A-006-MONT, "Hydrologic Instrumentation of Maynard Creek Watershed"; B-002-MONT, "Hydrologic Data Acquisition Through Remote Reconnaissance Systems"; and B-006-MONT, "Instrumentation of Remote Areas." B-014-MONT, "Digital Instrumentation and Telemetry for Water Resources Research" will be completed on August 31, 1969, and B-025-MONT, a continuation of B-002-MONT with the same title, has a completion date of June 30, 1970. Although much instrumentation will continue to be used on many of the Water Center projects, additional research and development work on instrumentation will be carried on with other than OWRR funding.

The research program of the Center indicates an increasing concern with problems of water quality. Completed projects include A-017-MONT, "A Study of Natural Water Systems in Western Montana"; A-018-MONT, "Effects of Logging on Small Stream Fisheries"; A-032-MONT, "The Effect of Copper on Algae of the Big Blackfoot River"; and B-009-MONT, "Industrial Organic Micropollutants and Protozoa." Continuing and new projects include A-027-MONT, "Microbiological Studies in an Open and Closed Watershed"; A-028-MONT, "Sourdough and Middle Creek Watersheds - A Comparative Study of Quality and Hydrology"; A-037-MONT, "Sculpins and Sculpin Parasites as Indicators of Stream Quality"; A-038-MONT, "Testacea as Indicators of Water Quality in Western Montana"; and A-040-MONT, "The Fate and Effects of Pesticides in the Aquatic Environment."

Several research projects of the Center will contribute to water resources planning. A completed study, A-025-MONT, "Computer Simulation of the Hydrologic System of a Mountain Watershed" is followed by a new project, A-034-MONT, "Comparison of Field Measurements to Computer Results of Mountain Watersheds." Another new project is A-033-MONT, "Planning for Multiple Purpose Water Resources Development." A major research effort of the Center is B-029-MONT, "Development of a Simulation Model for a State Water Plan" with matching funds of $111,150 being provided by the Montana Water Resources Board.

A research project for one year only (1968-69) has important implications for future research in the Center. Thirty-six faculty members participated in A-026-MONT, "A Study of Water Resources Research Needs in Montana."

Arrangements are being made for a Seminar on Water Law in October, 1969, to involve representatives of State and Federal agencies and others.

NEBRASKA

Warren Viessman, Jr., Director

Water is an exceedingly important natural resource in Nebraska and because of this the University is vitally concerned with developing useful programs in education and research which relate to the development, management and use of this resource. The Nebraska Water Resources Research Institute (NWRRI), in association with many University departments, state and federal agencies, and other organizations is engaged in the development of a comprehensive research program and the training of water scientists.

Important water problems faced by Nebraska and the region include floods, droughts, erosion, non-uniform distribution of precipitation, water quality deterioration, declining water tables, land drainage, effective water resources management, water rights, and the development of modern institutions capable of administering water resources programs.

The Nebraska Water Resources Research Institute is striving to contribute to the potential of the state for developing and implementing effective water resources programs. Research projects are being designed to effectively fill the information voids which now preclude the adequate solution of a variety of water resources problems. With proper coordination, much of the knowledge gained should be of a form suitable for objective use by planners, designers and decisionmakers in the conduct of their tasks. Well-planned research activities are being developed to explore feasible project alternatives in an unbiased manner.

Efforts are being made to coordinate the research program with the needs of the state water planning effort. Projects which should provide useful information to water resources planners include A-013, A-014, A-016, and B-003-NEB. These projects are designed to: (1) study the legal problems associated with the coordinated management of surface and ground water supplies; (2) explore the alternatives available for the water quality control of recreational lakes; (3) evaluate the feasibility of developing useful mathematical models for state water resources planning; and (4) study the suitability of various management practices for abating pollution from animal feedlots. Other useful research results are expected relative to: the recharge of municipal well fields using silt-laden streams (A-011-NEB); evapotranspiration mechanisms and control (A-001 and A-005-NEB); reduction of erosion and pollutional input through the employment of advanced land management practices (A-003-NEB); the economic development of small rural water supplies through desalination (A-007-NEB); the economics of developing irrigation projects (A-004-NEB); and the costs associated with pollution control in the meat packing industry (A-008-NEB). The results of most of these projects will be of immediate practical value.

Four research projects were completed in fiscal year 1969. The results of project A-003-NEB are being put to practical use in the design of soil and water conservation systems for Nebraska farms. Projects A-001 and A-005-NEB have produced considerable data which can be applied to the selection of crop types and design of physical controls for increased water use efficiency. A better understanding of the evapotranspiration process has also been an outcome of these studies. Project A-008-NEB has provided needed information on the costs of treating meat packing waste waters and the relative impact of these costs on the meat packing industry. The state Health Department and others concerned with water quality control are much interested in this kind of information.

The opportunity for expansion of the research effort is limited at present only by the shortage of financial support and the problem of attracting investigators from several important disciplines.

Effective working relations between the Institute and various state and federal agencies, other educational institutions, industries and other organizations associated with the water resources field have been established. A sound basis for cooperation in planning and conducting future research in association with these organizations exists. Several of the state agencies have been especially helpful in pointing out areas of research need. The Bureau of Reclamation and the Federal Water Pollution Control Administration have also been very helpful in this respect.

During fiscal year 1969, the Water Resources Institute sponsored or co-sponsored several seminars or conferences designed to meet specific needs. In general, these were of two types. The first employed the personnel engaged in water resources research on campus, and the second made use of invited experts on various aspects of the water resources field. A major seminar on evapotranspiration was held in June 1969.

Research findings and other activities of the Institute are from time to time reported on in the campus, local, and other newspapers. Short news releases are also carried by local radio and television stations when appropriate. A monthly news letter was initiated in May 1969 to provide current information on water resources to as many interested persons as possible.

The outlook for the NWRRI is very good. Productive research programs are established and the potential for future research is great.

NEVADA

William S. Butcher, Acting Director

Major current and anticipated water problems of the state and region may be classed in the following categories:

1. Problems centering around management and development of the resource.
2. Problems involving planning for optimal resource use.
3. Problems arising out of lack of knowledge of the resource.

In recent years it has been stated, and, for the most part accepted, that the surface waters in Nevada are fully appropriated and therefore put to use. This concept has, in turn, led to the idea that the only "new" water to be developed in the State is from the ground-water reservoirs. Actually it can be demonstrated that considerable additional amounts of surface water, as well as ground water, can be developed with more efficient management and development schemes, especially as demands for higher value uses occur. Further additional water can also be developed from more efficient use of water (i.e., irrigation efficiency in Nevada is reported to be about 25 per cent). Thus solution of these management and development problems is of great importance to the State and region.

Without careful and appropriate planning, efficient (or optimal) management and development programs probably cannot be devised. Adequate planning cannot be accomplished without certain lines of research, especially in methodology and data-handling and analysis. Thus all three categories of problems are closely related and interdependent.

The program of the Center to date and for the next few years is concentrated on development of a better understanding of the ground-water resource and of methodology which allows for more efficient, comprehensive interpretation of the available facts concerning the whole water resource. This program is especially well exemplified by our four-year statewide study of regional ground-water systems, development of management models for conjunctive use of ground and surface water in Las Vegas Valley and the Humboldt River Basin, and development of basin models in the Truckee-Carson area. Quality of water studies have been conducted on thermal springs and ground-water relations in mineralized areas. Also, under other sponsorship a quality of water study on the Truckee drainage complements the basin modeling. Support operations such as the organization of a Water Resources Data Center and a chemical laboratory are also significant contributions to the overall effort.

Applications of the research effort to practical problems are illustrated by the adoption and utilization of analog methodologies (developed by the Center) in Las Vegas Valley by the Las Vegas Valley Water District, on Colorado River by the Colorado River Commission of Nevada, and on the Humboldt River by the various water users. Management programming procedures developed at the Center are also being used in Las Vegas Valley. The Forest Service is using the results of Center studies on watershed soils to improve range and watershed management procedures. For the past several years Center methodologies in watershed analysis have been applied to problems encountered by the Department of Agriculture Basin Field Party in the Lahontan Basin operating under P. L. 566.

The research program has resulted in an improved training program for graduate students in hydrology, hydrogeology, and water resources. Many members of the Center staff teach in the program and supervise masters and doctoral theses. Most of these theses are based on Center research projects. The Center has also been able to encourage hiring of and partially supporting research programs for new staff members for several departments, most notably in the areas of systems analysis, law, and hydrogeology.

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The Center staff have actively supported and participated in the Nevada Water Conference, an annual affair. They also attend the Conservation Forum which is a monthly meeting of interested citizens from all walks of life. In the past few years the Center has actively cooperated with other universities in research projects, most notably with the University of Wisconsin and Pennsylvania State University.

NEW HAMPSHIRE

Gordon L. Byers, Director

Pollution in all aspects, as it affects water quality, is the major problem in water resources facing the state of New Hampshire today. This problem is far more complex than is recognized by most people, even some of those actively involved in the water resources field. Because of the many and varied demands placed on water resources in New Hampshire and apparent annual abundance, it is anticipated that the problem of water quality as it relates to the competing uses will become more critical. More detailed information is going to be needed on how to supply a uniform flow of water at all times in various degrees of quality to meet these demands. It is possible that the overall demand for industrial services may already override and exceed the demand and importance of household consumption.

The Water Resource Research Center is concentrating its efforts in the area of developing information for decision makers at all levels who are responsible for regulating water quality and quantity. Allotment Projects A-004, A-010, and A-013 are expected to provide information on control of the algae and thus contribute to the aesthetic and recreational use of water. Project No. A-013 is expected to develop methodology which will detect and enumerate disease-carrying viruses in surface waters. It is expected that this project can be expanded to include determination of how viruses are transported in surface waters. This will lead to control measures for regulating level of viruses in water. Projects A-009 and A-015 are expected to develop information that will contribute to the management of quality and quantity of water resources in New Hampshire by improved instrumentation and a better understanding of how to manage wetlands.

Completed projects such as A-003, A-007, and B-001 have produced results that are being used to improve water resource management. The projects have (1) developed a method of analysis that could be fully automated for determining quantities of trace elements in water -- commercial instruments are currently being developed by industry; (2) determined that the stabilization pond method for sewage disposal as an adequate and safe disposal system is very questionable unless a series of ponds and effluent chlorination is used and expert supervision is available at all times; and (3) found that fish subjected to sublethal doses of DDT have a higher mortality of eggs and are themselves very susceptible to mortality when food is scarce. These research findings will eventually lead to determining desirable and safe methods for handling wastes and pest protection.

The Water Resource Research Center is an active member of the New England Council of Water Center Directors, and assists in sponsoring Regional Resources Conferences through this council. It is expected that this council will take the leadership in initiating regional research on water problems. The Chairman of the Center is a member of the Environmental Technology Advisory Group organized to assist decision makers and planners on water resources problems in New Hampshire and Vermont. The Chairman of the Center attends as many state and regional water resources meetings and symposiums as possible. Other members of the faculty of the Center are also actively participating in state affairs, by working directly with those agencies involved with water resources; for example, the State Geologist. Academic contribution, in addition to graduate student and research support, includes support and interest stimulation in departmental sponsored seminars. Faculty members at St. Anselm's College and Franconia College are actively involved with the Center programs.

The State, through its Water Pollution and Supply Commission and Fish and Game Department, is contributing directly to the Center's program by providing boats and a mobile laboratory, and has installed some structures to facilitate the research work. The major problems are (1) limited supply of non-Federal funds for matching grant programs limits the expansion of the Center program, and (2) recruiting research proposals on the socio-economics of water resources.

NEW JERSEY

William Whipple, Jr., Director

Unquestionably, the main problems in New Jersey and the surrounding North Atlantic region are the rapidly progressing urbanization and its effect upon water quality and the environment. Not only technical, but economic, social and governmental organization problems are serious.

The main thrust of the State Institute program is now and is likely to remain upon three major fields: (a) organic pollution and biochemical oxygen demand of river systems, (b) urbanization as related to water resources planning and (c) economics of water resources. The institute program continues at a high rate of activity. On 1 July 1969, the number of active projects stood at 34, including major involvement from both Princeton University and Stevens Institute. Budget support continues to be given by the state for matching fund projects.

Projects A-018-NJ and B-014-NJ are expected to produce an important synthesis of viewpoint in water resource planning between the desired development of the water resources of the Mullica River, and the preservation of ecological values in the estuary and bay below. Determination of the best means of mixing density-stratified lakes is expected to result from B-005-NJ and B-024-NJ. Project B-002-NJ, besides important interim results noted below, is expected to demonstrate how economic growth in rapidly urbanizing river basins is correlated with total organic pollution loading of these rivers. The study of effects of pollution upon anadromous fishes (B-012-NJ) is expected to provide findings immediately applicable to water quality control on the Delaware River, as well as elsewhere.

Project A-016-NJ will provide much-needed analysis of government organization for pollution control in NJ, and suggest improvements; and Project A-029-NJ will conduct a similar analysis for water supply.

The project on Water Law in NJ (A-001-NJ) has produced an excellent paper which state agencies report has substantial value to them. Reports have been published on Projects A-005-NJ, B-005-NJ, B-008-PA, and A-002-NJ. Project A-014-NJ, "Economic Basis for Water Resources Analysis," has resulted in a book and several journal publications, two seminars at other major universities, and an application to the principles of flood plain economics made at the request of the Executive Director, Water Resources Council and since published. A major publication in book form, entitled "Instream Aeration of Polluted Rivers" resulted from an FWPCA demonstration project 16080DUP conducted in combination with three OWRR research projects, B-002-NJ, B-010-NJ, and B-011-NJ. Several papers have already resulted from this activity and others are pending. Based upon field tests and careful research into related aspects, the operating effectiveness and costs of instream aeration systems have been determined. An application to the Passaic River, NJ, has shown that an aeration system costing $194,000 annually would be as effective in raising dissolved oxygen levels as advanced waste treatment estimated to cost $785,000 annually. The project B-002-NJ, on Urbanization and Water Resources, has resulted in a finding of major importance not included in the original project objectives. A BOD mass balance analysis of three river basins showed that, of the total organic pollution entering the streams, less than half in each case could be accounted for as originating in recorded waste treatment effluents. This totally unexpected result has important policy implications, and calls for much more thorough analyses of the oxygen regimen of such rivers. Further research along these lines has already been authorized.

Among other activities, the institute director acted as summary speaker for the August 1968 conference on Urban Hydrology of the Engineers Research Foundation, as general chairman and theme speaker for the annual meeting of the American Water Resources Association, and taught graduate courses in economics and planning of water resources at both Rutgers and Princeton Universities. The institute also conducted the WRSIC center of competence for abstracting literature in the field of water resources economics.

Good relationships have been maintained with Federal and State agencies, including the State Departments of Conservation and Economic Development and of Public Health, the Corps of Engineers, the Federal Water Pollution Control Administration and the Delaware River Basin Commission. Relationships with the New Jersey office, U. S. Geological Survey include not only routine exchange of information, but exceptional cooperative arrangements. Contacts with other universities and meetings participated in are too numerous to be detailed.

NEW MEXICO

H. R. Stucky, Director

Current and Anticipated Water Problems - Water is the most critical resource problem in the State of New Mexico. Over 80 percent of the area of the state is in either the Rio Grande or the Colorado River drainage areas. These two drainage areas are the shortest of water in relation to projected needs of all the river basins in the United States according to the reports of the Senate Select Committee. Of the 1,009,930 acres of land irrigated in New Mexico, 521,710 acres are totally irrigated from groundwater only, and another 145,415 acres are partially irrigated from groundwater. The majority of the land irrigated from groundwater draws its supply from non-recharging basins. Some areas have now completely exhausted the storage, and up to 200,000 acres are moving toward that point at an accelerating rate.

The State of New Mexico would be greatly benefitted from an importation of water from the Mississippi River or from Canada and/or Alaska. However, the major questions upon which research is badly needed is how to program our present water supply to produce as much as possible in line with good conservation and multiple use principles. Almost 100 percent of the municipal and industrial water is obtained from groundwater supplies. Studies of the methods of preserving the quantity of the groundwater and of procedures for the most economical procedures for transfer of water from one use to another are greatly needed.

Main Thrust of Institute Program - The main thrust of the State Institute program during the next five years is likely to be to contribute information toward the development of a total state water plan. The Pecos Basin matching grant project B-006-NMEX and B-011-NMEX just being completed, and the Rio Grande matching grant project B-016-NMEX -- interdisciplinary-interuniversity studies -- are developing important basic data and basic concepts which will contribute to the state plan. In matching grant projects B-014-NMEX and B-015-NMEX, J. U. Anderson, is identifying the most potentially productive irrigated land for use in the state river basin planning project and for the future state plan. Annual allotment project A-006-NMEX (3109-63), Eldon Hanson and Boyce C. Williams, just ending, has proven by use of sub-surface irrigation that cotten yields could be increased by about 25 percent while at the same time the consumptive irrigation requirement could be reduced by about 20 percent.

Decision making models, gross systems analysis, more accurate analysis of hydrologic data, use of saline water resources, water recycling, control of water pollution, and scientific irrigation methods to conserve water are other items which will be emphasized.

Application of Research Results - The results of annual allotment project A-011-NMEX, R. E. Speece, "U-Tube Aeration", are being applied in the aeration of an effluent pond by the City of El Paso to reduce odors in a sewage reservoir. This same procedure has potential in adding oxygen to non-aerated water being withdrawn from the lower levels of reservoirs so this water will maintain fish life or avoid killing fish which may be in the water below the dam at the time the otherwise non-aerated water is released. The completed project, A-005-NMEX by H. E. Dregne, on salinity of water in crop production has contributed greatly to information on the effect of various quantities of saline water on yields of various crops. Matching grant B-005-NMEX by Frank B. Titus, "Geohydrologic Factors Affecting Rate of Evaporation from Moist Playas", is a classic study on the evaporation processes of playas in this arid area and contributes much to the scientific knowledge in this area.

Other Activities and Accomplishments - The Water Resources Research Institute projects are conducted by research investigators at New Mexico State University, Las Cruces, University of New Mexico, Albuquerque; and New Mexico Institute of Mining and Technology, Socorro. Two other state institutions, Highlands University, Las Vegas, New Mexico; and Eastern New Mexico State University, Portales, New Mexico, have been contacted regarding research proposals. The State Engineer Office, State Planning Office, State Health Department, State Department of Game and Fish, State Department of Agriculture, U. S. Geological Survey, U. S. Soil Conservation Service, U. S. Bureau of Reclamation, and the Federal Water Pollution Control Administration have actually participated in Institute research projects, and/or cooperated in making information available to research investigators and have representatives on various advising committees or consultant groups with the Institute project personnel. New Mexico State University Administration through President R. B. Corbett's office and through the Agricultural Experiment Station and Engineering Experiment Station administration has contributed greatly to the success of the Water Resources Research Institute programs.

Water Resources Research Institute Building - The State Board of Educational Finance has approved the New Mexico State University proposal for the construction of a Water Resources Research Institute Building on the New Mexico State University campus. The bids were advertised for opening on July 17, 1969. A period of 180 days is specified for completion following the signing of the construction contract.

Matching Funds - The State of New Mexico supplies funds for the several matching grant projects through the three University budgets where the research is conducted. It also contributes to consulting time through the several state agencies and through the university personnel who contribute indirectly to the research programs.

Annual Water Conference - The Water Resources Research Institute is the major sponsor for the Annual New Mexico Water Conference. The Fourteenth Annual Conference was held March 27-28, 1969. The proceedings of each of the fourteen conferences have been published and they have contributed much to the public understanding of the water situation in New Mexico and the Southwest.

NEW YORK

Leonard B. Dworsky, Director

With this annual report, the Cornell University Water Resources and Marine Sciences Center (the Cornell Center) concludes seven years of activity. Organized in 1962, the Center became effective in 1964 in response to the interest and support created by the Water Resources Research Act of that year (P.L. 88-379).

The primary objectives of water policy in New York and surrounding eastern states are:

- to free its citizens and their economy from the fear of floods and recurrent droughts;
- to control water pollution and to improve the quality of water resources to protect public health, increase recreation and fish and wildlife values, and to conserve the natural environment; and
- to improve the effectiveness of political institutions and laws that affect the management of water resources.

During the past five years the Cornell Center selected areas of study that could best contribute to these objectives, considering the capabilities of the University-faculty, students, facilities and money. An example of one study is that concerned with studies of the supply of water available in New York State and the Northeast in relation to present and future water demands. Two major water shortages in New York City within a decade; the provision of an adequate water supply to serve the growing population and industrial development of the Susquehanna River Basin; and the need for Syracuse to reach to Lake Ontario for its future water supply help to explain the importance of this study.

Professors D. J. Allee, H. E. Conklin, M. L. Falkson, L. B. Dworsky and G. S. Levine in cooperation with Graduate Students reported on recreational, industrial, agricultural and municipal water supply availability and demands. Part of the results of these studies have been used by the Corps of Engineers in planning for future water needs in the Northeast, by the New York State Agricultural Resources Commission appointed by Governor Nelson A. Rockefeller, and by the program of the New York State Water Resources Commission and other agencies. (A-001-NY), (B-002-NY), and (B-014-NY).

A second illustration involves the application of modern management techniques to water problems. The application of systems analysis methods to a wide range of single and multi-purpose water management problems (e.g. water pollution, flood control, irrigation, hydro-electric power) involving mathematical procedures and computers is gaining in importance. Professor D. P. Loucks has developed procedures for determining alternative policies to achieve various goals under conditions where several water purposes have to be served. This program has led to a program in which Professor Loucks representing Cornell has joined with faculty members of Harvard University to develop programming models for the Delaware River. (A-010-NY and C-1640).

During the past two years the Cornell Center has brought to completion a major study on the Modernization of Eastern Water Law (Professor W. A. Farnham, B-003-NY), has carried out and strengthened its program in the aquatic environment (the Great Lakes and the Finger Lakes of New York State) (J. P. Barlow, A-007-NY; W. H. Brutsaert, A-009-NY; C. D. Gates, A-012-NY; A. W. Eipper and C. A. Carlson, A-013-NY; M. Alexander, A-014-NY; R. G. Young, A-015-NY; D. A. Webster, A-019-NY and R. T. Oglesby, A-025-NY); continued to assess current processes and assist in the development of new advanced waste treatment technology for pollution control (Professors A. W. Lawrence, A-016-NY and V. C. Behn, A-017-NY); and has pursued studies concerned with the improvement of water management institutions for pollution control and River Basin Commissions. The latter study is being carried out in cooperation with the New England River Basin Commission and the National Water Resources Council (Professor L. B. Dworsky, C-1925).

During the past five years the Cornell Center has been able to maintain a program outlined initially during 1964. If criteria for measuring success are participation by faculty and students from a large proportion of the university's colleges; production of useful knowledge on questions of concern to society; and translation and distribution of that knowledge to government agencies, universities, industries and others; the Cornell program can be called successful. In addition to these direct results, the Cornell Center has played a more subtle role in maintaining a visibility for water and related resources research and training and has provided a focal point for public service activities that otherwise would not exist. Under these criteria, it is apparent that the achievements anticipated by the Congress are being attained.

For the period 1970-74 the Cornell Center proposes to concentrate on the development of an improved technology to more effectively control water pollution; to strengthen its efforts in the aquatic environment with significantly greater efforts in the Great Lakes, the Finger Lakes and adjoining Lakes of New York; to contribute to the identification of weaknesses in government institutions and to recommend ideas for institution building at local, state, regional and national levels for the improved management of water resources; and to concentrate on urban water problems with special reference to the planning and social problems of the urban community.

There is a great interest on the part of faculty and students to attack important social problems. Water problems such as water pollution, urban water management in relation to urban living, conserving lakes and the natural environment and modernizing law and government characterize a class of social problems that can be attacked by universities and their Water Centers. The rate of such an attack is dependent upon the availability of funds. The recommendations (in the Resolutions of the 5th Annual Meeting of UCOWR) if adopted, would enable the universities to utilize their ability to provide new knowledge about these problems and to bring this knowledge effectively to using persons and organizations. With the increases contemplated, the Cornell Center could make substantial improvements in the program during the next five years.

NORTH CAROLINA

David H. Howells, Director

North Carolina's water resources are generally abundant, but rainfall and storage vary considerably in time and space. Periods of excess and drought are relatively common. There is also a lack of harmony between the distribution of population centers and available water resources.

A proliferation of small community water and sewer systems with associated deficiencies due to poor planning and operation demands attention. There is no established procedure to assure coordination of actions taken at the local level or the consideration of alternative arrangements for the provision of services. The absence of a clearly established responsibility for comprehensive planning of water and sewer services throughout the state has been a limiting factor. Another is the lack of a State Water Plan relating the available water supply to existing and future demands as a framework for the efficient utilization of both ground and surface water resources. The Water Resources Research Institute joined with the Institute of Government in sponsoring a statewide symposium on December 4, 1968, calling attention to the problems and need for action. A summary of the principal findings was sent to the legislature, the Governor and principal state officials.

A multicounty region encompassing the estuaries of the Neuse and Pamlico Rivers is currently experiencing difficulties with the principal ground water supply of the Coastal Region because of dewatering operations associated with open-pit phosphate mining. The reduced pressures in the artesian aquifer threaten salt water intrusion and the region has been declared a "capacity use area" with state regulation of water use. The Institute has undertaken research leading to the development of an electric analog model to guide water management (A-026-NC and B-005-NC).

The Pamlico River Estuary will be markedly changed as a result of phosphate mining and related industrial and population growth. The quality of estuarine waters is important because of their value as fishery nursery areas, for commercial and sports fisheries, and recreational use. A major Institute research effort has been directed toward this problem since 1966 (B-004-NC and A-030-NC).

Present drainage practice in the Coastal Plain threatens destruction of one and one-half million acres of organic soils, interference with fish and wildlife habitat, and ground water recharge. Other agriculture water use problems include pollution from agricultural chemicals and animal wastes. All of these were discussed at a Workshop on Agricultural and Water Use sponsored by the Institute on March 14, 1969. Research on fertilizer loss to surface and ground waters, the design of a pesticide monitoring system, and criteria for drainage and irrigation is being sponsored by the Institute (A-031-NC, A-021-NC, and A-033-NC).

The Outer Banks are of great importance to the state for their recreational value and protection of the mainland from the open seas. A key factor to both is the continued availability of the limited fresh water supply. A related Institute study in close cooperation with the Geological Survey is currently underway. (B-006-NC).

Streams feeding authorized new impoundments in North Carolina carry sufficient nitrogen and phosphorus to create excessive algal growths and related water quality management problems. Two major Institute projects are directed toward this problem (B-003-NC and B-007-NC).

Some sections of the state are now confronted with the need for the highest possible degree of waste treatment to comply with water quality standards in receiving streams. A study of pollutants contributed to the Research Triangle area by surface runoff from a typical urban watershed in Durham was undertaken last year to develop information in this area. (A-034-NC).

Water quality problems from industrial wastes in North Carolina come largely from the textile, pulp and paper, and food-processing industries. The practice of dealing with industrial wastes primarily as treatment problems inflates the cost of remedial action. Waste treatment is expensive and should be the last resort. Such alternatives as more efficient water use, chemical substitution and recovery, process change, waste by-product development, and other internal means offer many possibilities for substantial cost savings to the industries involved. Because of the steady demand for a decrease in waste discharges by industry in the face of rising production, every effort must be made to eliminate wastes at the point of origin as well as to forge ahead with the development of improved treatment techniques. The Institute has a number of research projects looking into various aspects of industrial water use and waste control (A-035-NC, A-036-NC, A-032-NC, and A-037-NC).

Land development in the vicinity of large multipurpose reservoirs poses many problems in water resource management. Demand for reservoir shoreline usage is increasing rapidly, and conflicts between uses of the reservoir and shoreline development are becoming acute. An important Institute project involves the development of a forecast model for the testing of alternative policy mixes for their effectiveness in promoting desirable land development patterns around multipurpose reservoirs (B-012-NC). A concurrent study of the Durham Municipal Watershed is investigating the effects of various types of land use on water yield, quality and cost (B-010-NC).

Vast areas of North CArolina offer almost unlimited opportunities for the development of a water-based recreation industry. The absence of rationale for estimating the recreation capacity of natural and artificial bodies of water leaves an ever-widening gap in the credibility of resource development plans. The Institute is presently formulating concepts and methodology for estimating the volume of recreation use which can be properly supported by various types of waters (B-013-NC).

Thirty-seven communities in North Carolina have requested flood information studies from the Corps of Engineers, U.S.G.S. or T.V.A. Yet, very little community action has materialized following completion of the studies. The Institute sponsored a workshop to identify additional steps which might be taken by action agencies and/or research needs.

The main thrust of the Institute program in the next five years will be focused on water resources planning and water quality management. This will be guided by an advisory committee under the chairmanship of the Director, North Carolina Department of Water and Air Resources, and Institute studies on research needs, faculty research interests in all universities of North Carolina, and inventories of research--information and data (A-018-NC and non project studies).

The North Carolina legislature recognized the importance of Institute research to the management of the state's water resources by approving the full amount of the University's appropriation request for the Institute program during the 1969-1971 biennium.

NORTH DAKOTA

Dale Anderson, Director

Various state and federal agencies are charged with the responsibility of developing and implementing plans for effective water resource development and use to enhance the economic environmental growth of the State. The development of an imaginative, forward-looking research program, providing vital development and planning information, is essential to the formulation of sound decisions for developing and implementing effective water use programs. The Institute has provided the catalyst to initiate a considerable amount of much needed research on problems related to water conservation and development in North Dakota.

Current water problems in North Dakota relate largely to the development and management of agricultural uses of water. Data are needed for planning, developing, and implementing irrigation on an individual farm basis. A simulation model developed in Project B-007-NDAK will make it possible to select the appropriate irrigation system capacity and associated management scheme for a given set of land and capital resources, as well as expected weather conditions and crops irrigated. However, additional research is needed to measure the value of water for irrigation and to plan the most efficient use of water. Another current problem is need for accurate measurement of the total impact (economic, sociological, and institutional) of water resource development. The economic impact of irrigation development was estimated in Project B-002-NDAK. This research must be expanded. An empirical identification of pollution in lakes and streams from agricultural sources such as fertilizers, herbicides, insecticides, and animal waste is becoming more urgent. Three projects, A-001-NDAK, A-009-NDAK, and A-010-NDAK, focus attention on animal waste disposal systems.

A problem of particular concern to the prairie pothole region is a feasible wetlands management system. Research is needed which will provide data to serve as the basis for developing an equitable land use management program. Also, intensive study is needed to measure the impact of the proposed restoration of Devils Lake and Stump Lake on the water quality in the Sheyenne River. Salinity levels need to be identified that can be tolerated by various species of fish and wildlife proposed for enhancement in the area. Research being conducted in Projects A-014-NDAK and A-026-NDAK is providing and will continue to provide much useful data for future planning relative to the restoration of Devils Lake and the resulting economic, social, and institutional impact to the area and State.

Many current water resource problems will not be resolved in the next five years. Water problems of North Dakota will become even more complex in the future. Future economic development and growth of the State will be greatly influenced by an adequate quantity and quality of water. To provide the most relevant research results in water resources development during the next five years, the research program of the Institute will direct its primary emphasis to the following general problem areas: (1) identification of major sources of agricultural pollution, (2) development of effective measures to control agricultural pollution where necessary, (3) reduction or control of algae in North Dakota lakes and ponds, and (4) control of wetland ecology. Very little research has been directed toward the identification of agricultural pollution in North Dakota. Continuation of research being conducted in projects A-011-NDAK, A-014-NDAK, A-015-NDAK, A-017-NDAK, A-018-NDAK, and B-001-NDAK will provide much relevant data for improving management and use of North Dakota lakes and ponds.

Increased research is needed on socioeconomic, legal, and institutional problems. Research funded by the Institute in this area to date has only scratched the surface. Economic impact of irrigation development on a multi-county area was studied in projects B-002-NDAK and B-003-NDAK. This research will have to be expended to measure the economic impact of all water development. In addition, research designed to measure the sociological, legal, and political impact will be initiated. More work is needed on engineering problems in water resources and new projects will be developed in such areas as channel design, methods of water treatment, pipeline studies, and recreation development from diversion of Missouri River water.

Additional information is needed on the hydrology of water resource development. The most urgent problem in this area is pothole hydrology. Other problem areas to which research will be initiated include (1) quantity and quality of return flows from gravity and sprinkler irrigation, (2) ground water movement, (3) thermal pollution, and (4) criteria for water quality standards.

Results obtained from B-002-NDAK have been used by state and federal agencies to show the impact of irrigation development in North Dakota on the total economy. Agencies have used these data to justify appropriation requests before legislative committees. Results of A-014-NDAK and B-001-NDAK have been particularly useful to civic groups and State agencies concerned with algae problems in North Dakota lakes. In addition, research results obtained from A-014-NDAK have been useful in planning for the restoration of Devils Lake and Stump Lake.

The Institute has cooperated with other organizations and agencies in planning for the development of the water resources of the State and region. Institute activities have been coordinated with work being undertaken by the Souris-Red-Rainy River Basins Commission and the Missouri Basin Inter-Agency Committee. The Director represents North Dakota on work groups in these two planning bodies. Assistance has been provided to the North Dakota State Water Commission in preparation of the State Water Development Plan. The Institute has also worked with the North Dakota Wildlife Advisory Committee in the formulation of possible programs to preserve wetlands.

The executive committee of the Institute is the Project Committee which is composed of three members each from the University of North Dakota and North Dakota State University. It acts on Institute policy and receives, reviews, and makes recommendations regarding research to be conducted by the Institute. In addition, the Institute receives counsel from an Advisory Committee, consisting of 33 members, representing state and federal agencies involved in water-related activities.

OHIO

K. S. Shumate, Acting Director

Current and Anticipated Water Problems.

Current and anticipated water problems of the state and region are essentially those of water quality. Concern is being expressed regarding the condition of Lake Erie. The continued disposal of waste effluents, both municipal and industrial, into the drainage basin has raised several questions concerning the overall outcome. It has generated considerable studies and, in the Cleveland area, precipitated a multi-million dollar program to reduce the contaminants entering the Lake.

In Southeastern Ohio the acid mine drainage problem remains the most significant deterrent to good water quality.

In Northwest Ohio both quantity and quality problems have been considered in a plan now underway to provide for water resource development, largely with upground storage reservoirs, to support anticipated growth and development of the region.

In relation to these problems, it is anticipated that the major thrust of the Ohio OWRR program is in the area of water quality, specifically oriented toward Lake Erie. Further, it is anticipated that this emphasis will continue for the next three to five years. Current projects in this area including A-006-OHIO, A-007-OHIO, A-008-OHIO, and B-013-OHIO are evaluating factors affecting the lake ecology. Project A-009-OHIO is attempting to evaluate public investment criteria for water-oriented recreation in the Lake Erie Basin. Projects B-017-OHIO and B-023-OHIO are supporting a systems analysis approach, providing for more economic studies of the area, and correlating the socio-economic sector through factors influencing water quality criteria. Another new project, A-018-OHIO, will evaluate effects of agricultural land runoff into the lake. Results from this study will also be incorporated into the overall systems analysis approach. Hopefully, results of the individual efforts and of the combined overall study will provide more meaningful results regarding significant contaminants and nutrients entering the lake, and their inter-effects on the lake ecology and on the contiguous socio-economic sector.

Application of Research Results.

None of the results of completed projects are being applied directly to solve water problems. However, the acid mine work in particular (Projects A-001-OHIO and A-002-OHIO) have generated further work which is hopefully reaching a stage that might generate practical and more optimum remedial measures.

Other Activities and Accomplishments.

The Water Resources Center, during the past year, has actively promoted more involvement in water resources training, and staff from the Center cooperating with the School of Natural Resources were effective in obtaining a larger Federal Water Pollution Control Administration grant for interdisciplinary training in water quality control of masters level students. In addition, the Center recently participated with the School of Natural Resources in a joint seminar to consider water management training. Results of this seminar are now being assessed, with the idea of evaluating the need for such a program at this institution.

The Water Resources Center has also sponsored a seminar on water quality and treatment, during the past year, and has invited several distinguished guest speakers to participate. This seminar is being incorporated as a part of the program for graduate training of water resource oriented engineers.

OKLAHOMA

Marvin T. Edmison, Director

Oklahoma is a transition state in several respects. First, like many other parts of the country it is undergoing alteration from an agriculturally oriented society to a more industrialized, urbanized complex. Oklahoma is also a transition state climatologically. Rainfall varies from approximately 56 inches per year in the southeast to 16 inches per year in the far northwest. Runoff from rainfall likewise varies from over 20 inches per acre to less than .2 inch per acre.

Grazing has largely replaced much of the row cropping of earlier years while a most dramatic change is being brought about by irrigated crops which now comprise over 600,000 acres, mostly in the arid western part of the State.

Oklahoma has over 250,000 farm ponds and approximately one-third of all the USDA upstream flood control reservoirs that have been constructed in the United States. Additionally, Oklahoma contains 50 major reservoirs including 35 mainstream reservoirs of over 1,000 surface acres. As a result of these impoundments, water based recreation is a major industry in the State.

By the end of 1970, it is anticipated that the Arkansas River navigation project will be open to barge traffic from the Port of Catoosa near Tulsa to the Mississippi River. The industrial and recreational potential of the waterway is immense and is already of considerable impact.

In both quantity and quality, Oklahoma has more than adequate water supply to meet all anticipated requirements for the next 100 years. However, because of unequal distribution, wide variations in quality, and highly localized demand, critical water problems already exist.

The Oklahoma Water Resources Research Institute, therefore, has established a diversified program to seek better understanding and possible solutions to the major water problems of irrigation, recreation, and navigation that now exist in Oklahoma. The Institute has three projects directly concerned with aquatic ecology and water quality of ponds or lakes; one project concerned with suppressing of evaporation from exposed surface water; one project directly concerned with more uniform distribution of irrigation water, particularly channel design for efficient water application and a project studying the hydrology of sheet flow of water over vegetated surfaces and slopes.

Three Institute Projects are investigating various aspects of water quality maintenance: (1) improved quality of output of waste treatment plants; (2) nutritional pollution; and (3) an extended aeration process of waste water treatment.

A project investigating the thermodynamic properties of saline waters and another exploring the economic effect of the Arkansas waterway on land values along its route, complete the Institute's current allotment program. Projects involving study of reuse of surface runoff of irrigation water and the methodology of allocating resources to water research will be added during the coming year.

Two matching grant projects are concerned with the efficient use of water in crop irrigation while a third project, now nearing completion, is an intensive study of the Arkansas River and its sub-basins in Eastern Oklahoma.

The Institute is directly associated in research with the Oklahoma Water Resources Board, the University of Oklahoma, the City and County of Tulsa, the Department of Agriculture's Water Conservation Structures Laboratory and, indirectly, through mutual cooperation of scientists, with the Federal Water Pollution Control Administration's Kerr Laboratory, the Department of Agriculture's Agricultural Research Service, the U.S. Corps of Engineers, the Oklahoma Cooperative Fishery Unit, the Oklahoma Cooperative Wildlife Unit, the Oklahoma Department of Wildlife Conservation, the Oklahoma Refiners Waste Control Council, and the many other non-Institute projects at the University. Students and trainees of the Federal Water Pollution Control Administration, the Corps of Engineers, the Oklahoma Fish and Game Council, the Max McGraw Wildlife Foundation, the Oklahoma Economic Development Foundation and others participate in various Water Resources Projects.

Though not technically a part of the Institute, both the Oklahoma Cooperative Fishery Research Unit and the Oklahoma State University Reservoir Research Center conduct research programs in close liaison with Institute projects. The Fishery Unit has eleven fish culture ponds and plans an enlarged facility which will include nearly 50 ponds of some 20 surface acres total.

The Oklahoma Water Resources Research Institute is a joint participant with other states of the central United States in the Mid-Continent Association of Water Research Institutes. A recently held evapotranspiration conference and a forthcoming agricultural pollution conference are both under the sponsorship of the aforementioned organization.

During the spring of 1969, Dr. Bernard Patton, Professor of Zoology, University of Georgia, conducted a three-day interdisciplinary seminar on ecosystems analysis for water resource scientists on the campus. The 20 participants represented the departments of Zoology, Chemistry, Bio-chemistry, and Agricultural Economics.

The number of students receiving advanced education in the various aspects of water resources has undergone a significant growth in the last year. A comparison with last year's figures indicates a growth in excess of fifty percent. Additionally, more courses of an interdisciplinary nature are being taken by graduate students aware that the truly encompassing nature of water and environmental problems demands more comprehensive knowledge. The growth in both numbers of water scientists and of their capabilities coupled with an increasing public awareness of the complexities of water problems gives promise that our water heritage can and must be preserved.

OREGON

Emery Castle, Director

Oregon must determine how it can develop its potential water supply for all beneficial uses within the state. During certain times of the year practically every stream is either over-appropriated or so severely depleted that the flows are inadequate to meet minimal requirements. The problem is emphasized by conclusions reached in a four-year study of longe range requirements for water published recently by the State Water Resources Board. Oregon will be a water deficient state in the year 2070, the report states, because it will not have enough water within its borders to fulfill its total requirements.

Economical water storage will continue to be a most important catalyst in developing Oregon's timber, agriculture, and mineral wealth, as well as providing recreational opportunities. Oregon water users, in general have developed the least expensive storage sites within their areas. Known sites, with relatively small dams with water-tight abutments, are not plentiful. Some means of protecting potential reservoir sites are needed to preclude construction within these areas which would render the site uneconomical for development by water use interests. Natural resource agencies, planning commissions, and water use interests must collaborate on area land use planning to include site zoning.

Legal matters demand attention. The major portions of the Willamette, Umpqua, and coastal drainages have not been adjudicated. Until this is completed, the status of major claims to water and the resulting effect on existing water rights cannot be determined. Equally pressing is the problem of providing assurances required by federal law. PL 86-700 requires assurances and contracts for future municipal and industrial water supplies that would be stored in federal projects. PL 89-72 requires re-payment by non-federal interests of one-half of the separable costs assigned to fish, wildlife, and recreation enhancement pertaining to federal projects.

The state's constitution does not permit such participation by the state. In the absence of a constitutional amendment, it will be necessary to continue to look to local government entities, such as counties, municipalities, and special districts, to meet the requirements of federal law. The 1969 Legislature approved a multi-purpose local entity which could cooperate with federal agencies in water resource development. The law authorizes formation of water improvement districts with power to levy an ad valorem tax (within limits), borrow money, sell bonds and adopt regulations and cooperate with federal agencies. Research performed under A-002-ORE helped to muster arguments in support of this important legislation.

Recreation requirements are burgeoning. In cooperation with State agencies, the Institute is surveying Oregon's lakes (A-003-ORE) to determine future outlook. At the same time, research is proceeding to gauge the effect of thermal pollution on fish populations (B-012-ORE) and the enhancement of water quality by diverting heated effluents to agricultural use (B-009-ORE).

Two public seminars were conducted by the Institute during the school year, with the proceedings published in booklet form and distributed widely. The Fall Quarter series was devoted to "Reservoirs: Problems and Conflicts" and the Spring Quarter discussions covered snow and ice hydrology under the general title of "Snow". All sessions were attended not only by students and faculty, but also members of appropriate State and Federal agencies. Institute members attended scheduled meetings of the Willamette Basin Task Force, the Columbia-North Pacific Task Force, the Pacific Northwest River Basins Commission, and the Western States Institute Directors. Dr. Castle, Director of the Institute, was named by the Governor as Chairman of the State Water Resources Board.

During the next five years it is expected that research at Oregon State

University will proceed somewhat along the following lines: physical sciences - watershed management, irrigation and agriculture, river systems and development; biological sciences - water quality and waste treatment, fisheries biology, aquatic vegetation, lakes; social sciences - water law and institutions, decision making processes, fresh water economics, geographic-regional planning and legislation.

Efforts of Institute members, in coordination with other individuals and agencies in the state, resulted in passage by the current Legislature of a state-wide zoning law. A comprehensive land use plan, or zoning regulation, on a county by county basis, is to be developed. State plans will relate to intermediate and long-range growth objectives and are to set a pattern upon which state agencies and local governments may base their programs and local area plans. The goals include preservation of water quality, provision of recreational facilities, enhancement of natural resources, and flood management. The next five years will see close liaison between governmental representatives and the academic community in attaining these goals.

The University will continue to offer each year appropriate short courses in its education program regarding water resources. During the period under review, the following attracted wide attendance: "Natural Resources Economics Institute" to demonstrate the use of economics as an admimistrative tool in natural resources development; "Sewage Works" a short course to train operators in modern technology; "Water Works" a short course to train operators in latest developments; and an "Industrial Waste Conference" for industrial plant managers to discuss waste and water problems in industry.

PENNSYLVANIA

John C. Frey, Director

The current program objectives of The Pennsylvania State University's Water Resources Center correspond very closely with a state-wide classification of water resources research needs in Pennsylvania. This general classification of research needs was developed during a workshop in May 1969 on water resources research planning in which specialists from state agencies, industry, and Pennsylvania's institutions of higher learning took part. Constituting the five headings of the classification are: (1) Water supply and acid mine water abatement; (2) Communications and manpower for water management programs; (3) Institutions for water management programs (legal, economic, political, and social); (4) Optimization of engineering designs and operations; and (5) Process containment.

Under the first heading, one thrust of the Water Resources Center over the next five years will be to conserve, increase, and replenish groundwater supplies for economic development. This thrust also will extend to increasing stream yields for low flow augmentation, community water supplies, and related purposes; stepping up the use of new and more efficient methods of treating and disposing of water of impaired quality, including acid mine water; and flood control. Contributing to these aims in the past year were: Projects A-002-PA, A-005-PA, A-006-PA, A-013-PA, A-015-PA, and A-016-PA under the allotment program of the Water Resources Center. Accomplishments include: The development of engineering design parameters for the use of limestone barriers to neutralize acid streams; defining basic elements required to analyze the hydraulic response of carbonate aquifers under groundwater development; and development of a numerical model for the simulation of water flow into a simple pumping well.

Also among the major accomplishments are an analysis of characteristics influencing water yields, flow durations, and high-flow timing in 25 small watersheds; preparation of a descriptive mathematical function for the time distribution of rainfall intensities in rain storms; and compilation and analysis of an annual series of instantaneous maximum discharges for 86 watersheds. Much of the work now under way in watershed hydrology and flood control will continue during the forthcoming year.

A state-wide survey of water resource problem areas and constraints has been a single effort under the second heading, "Communications and Manpower." Survey results will be made generally available to the public. Plans for the development of additional projects in this area already are initiated.

Under the third heading, the chief objectives of Water Resources have been to improve the legal and institutional arrangements by which water resource use is controlled, and to increase the efficiency of public investments in water resource development projects. Contributing projects under the allotment program were A-009-PA, A-014-PA, and A-017-PA. Progress in this area includes: development of an input-output model of economic activity and water usage in a micro-region; current designing of an econometric model to measure impacts of sewage systems and to assign priorities to sewage facilities grants; and the start of a sociological study of the impact of a flood control reservoir on a community. Also contributing is a matching grant project still in progress (B-012-PA) which seeks to derive estimates of the regional costs of pollution in terms of recreational development foregone. This project has developed a unique methodology for analyzing the anticipated disbenefits of pollution.

Under the fourth heading, the cardinal aim of Water Resources has been the efficient disposal of municipal storm water, sewage effluent, and acid mine water. Here, three lines of investigations are actively being pursued with multiple sources of funding. One of these lines is project B-010-PA with the Office of Water Resources Research. This effort has resulted in an evaluation of urban hydrology design methods for storm water planning.

The fifth major area of endeavor encompasses Water Resources' aim to remove and control undesirable biological growth in lakes and streams, and the prevention of groundwater contamination by municipal and industrial wastes. Allotment projects A-003-PA, A-018-PA, A-019-PA, and matching grant projects B-001-PA, B-016-PA, and B-020-PA fall under this classification. Presently completed is an analysis which demonstrates the relationship between plant growth in streams and nutrient level, sunlight intensity, and stream hydraulic characteristics. Estimates of the impact that a respiring plant population can have on the oxygen economy of a water resource also have been made. Research has been initiated to identify detergent residues in polluted water by application of laser ionization mass spectrometry. And with this, an examination has been started of the microbial composition of activated sludges before and during chemical treatment of waste waters for phosphorus removal.

Early work in the area of waste water renovation demonstrated that sewage can be disposed of at a reasonable cost by applying it to crop and forest lands on a year-round basis. A major project now underway by Water Resources is a test of the filter concept of irrigating waste water on land to renovate the water and increase the amount of groundwater going into groundwater reservoirs. This continuing project will reach fruition with the completion of a system for the daily disposal on the land of four million gallons of sewage effluent from the State College, Pa., community. More than $2 million already has been awarded to the University for construction of the waste water system.

Finally, completed project A-002-PA, "Crushed Limestone Barriers for Neutralization of Acid Streams," already shows promise of contributing to Pennsylvania's water pollution abatement program. Through this research project, scientists at

Water Resources have revealed that crushed limestone barriers can be used in streams contaminated with acid mine drainage to reduce the acidity in the water. Their studies indicate that a barrier installation can have any reasonable number of units and be of such stone size as to be compatible with the site topography. Based on research results developed in this investigation, The Pennsylvania Department of Mines and Mineral Industries presently is designing a prototype installation on Trough Creek, Huntington County, Pa., to observe field potentials. The facility is expected to be constructed and placed into operation by the middle of 1970.

To facilitate the continued growth of the Water Resources Center, Dr. Archibald J. McDonnell, Associate Professor of Civil Engineering, has been named Assistant Director for the Institute for Research on Land and Water Resources. Dr. McDonnell will be in charge of the Water Resources Center, succeeding Dr. E. Bruce Jones who has accepted a position with E.G.&G., Inc., Boulder, Colorado. The appointment is effective July 1, 1969. Other appointments and personnel changes will be made and the Advisory Council of the Institute will be reconstituted, also effective July 1, to provide up-to-date representation from each of the University's major colleges.

PUERTO RICO

Ernesto F. Colon, Director

The urgent need for an interdisciplinary research program here in Puerto Rico was the original motive for the establishment of the WRRI.

All available evidence clearly indicates a continued and increasing need for such research. Latest information from government sources indicates that our industrial growth has accelerated significantly during the past five months. There is no reason to believe that this acceleration will end. On the contrary, the general expectation of a more vigorous economic growth in the years to come seems well supported. This situation demands an even increasing effort in the identification of water problems lying ahead of us. Good quality water in the right amounts requires good management and control. But there can be no proper management, control, and design without the necessary scientific data to provide the facts on which to base the necessary engineering and economic decisions. The WRRI exists to provide these facts.

Water problems are encountered in the identification of sources and the fate of pollutants in rivers and bays; water demand; conservation in domestic use; hydrology of watersheds; water-based recreation; ground water management; and most important, the impact of man, socially and economically, on water resources.

In an attempt to alleviate pollution problems on the island the Institute has sponsored a series of projects in this area. Some of these are: "The Determination of Safe Levels of Pollution in Some Bays of Puerto Rico," "Self Purification Rates of Polluted Streams in Puerto Rico," and "Determination of the Rate of Biodegradation in Some Polluted Tropical Waters and in Some Types of Liquid Wastes Common in Puerto Rico." These studies will be a useful contribution toward maintaining water quality in the island.

In the area of water demand, tangible results have already been realized in the project "Quantitative Analysis of Water Use Patterns in Puerto Rico." The results of the industrial phase have produced reliable estimates on the amount of water required by factories to produce a unit of certain selected products (water ratios) which will be of value in improving industrial location and site planning in Puerto Rico.

More results in this area are envisioned with the completion of the project "The Determination of the Significance of the Variables affecting Residential Water Consumption", which will attempt to provide an accurate prediction of water consumption in residential areas using the theory of 'fractional factorial designs'.

The hydrology of the numerous watersheds in Puerto Rico is practically unknown. However, the Institute has sponsored a project "Hydrologic Study of the Yaguez River Watershed." The Yaguez River, a short distance from the Institute's headquarters, is a constant menace to the residents of Mayaguez who have experienced large economic losses due to constant flooding of this river. The results of the study will provide information to the Public Works Department, which has exhibited keen interest in the project by contributing financially.

Water-based recreation constitutes an integral part of the tourist industry which is a primary income generator for the island. In this area, no research has been done and for this reason, the project "Demand for Water-Based Recreation in Southwest Puerto Rico" was developed with the hope of providing a critical evaluation of factors affecting the development of water-based recreation.

Other projects such as: "The Impact of Water Resources on the Economic and Industrial Development of South Puerto Rico," will examine how man's activities have affected the management and development of water resources on the island.

As in former years, the Institute participates actively both in public and academic affairs, such as sponsoring a symposium in cooperation with the Office of Water for Peace, entitled "Land and Water Resources Planning Education in Latin America" in which practically all countries in the Caribbean and Latin America were represented.

During the last fiscal year, a direct allocation ($25,000.00) from Commonwealth funds through the University was provided for the first time. As originally recommended by Dr. Antonio Santiago Vazquez, former Director of the Institute now Secretary of Public Works of the Commonwealth of Puerto Rico, an advisory Committee to the Director was appointed. It is composed of twelve interdisciplinary faculty members. The former Director of the Puerto Rico Aqueduct and Sewer Authority is also a member of this Committee.

The problems encountered in administering the program may be divided into two broad areas: First, as it is not a separate administrative research unit the Institute must depend on the systems and procedures long established at the University of Puerto Rico. These arrangements do not respond to the unique needs of investigators but rather traditional academic routine. However, good progress is being made in changing old concepts and procedures. The Administration of UPR has been most cooperative in the process of establishing more efficient cost and procurement methods to suit our needs.

Second, the distance from the mainland, the higher costs for everything here in Puerto Rico and the inadequacy of funds, both Federal and Commonwealth, constitute a permanent problem.

RHODE ISLAND

A. Ralph Thompson

Rhode Island's Current and Anticipated Problems

The Rhode Island Water Resources Center has taken an active interest in water problems of concern to the State as well as the New England region. The location and climate of Rhode Island have supplied it with an excellent supply of fresh water so that, if it is handled properly, the State should not require additional water sources for some years. In order to preserve the supply, however, it is well that consideration is being given to the problems of conservation, storage, pollution, re-use and alternate sources, such as desalination, far in advance of a possible crisis.

As in many other sections of the country, one of the main problems in Rhode Island occurs as a result of the conflict in the alternative uses of water. In the proposed development of the Big and Wood River reservoirs thought has been given to all possible uses of the water. Industrial pollution of streams must, of course, be given constant attention and research at the Center has helped to solve problems in this area. A specific State problem which has been handled by the Center in cooperation with the State Water Resources Board and the U.S. Geological Survey is the presence of high concentrations of iron and manganese in groundwater supplies. OWRR project A-003-RI and A-017-RI have made valuable contributions to this problem.

Main Objectives of the Center

Since the Center began, it has had as its goals:

(1) Determination of the condition of water in the State and preparation for future needs and alternate sources.

(2) Alleviation of water pollution through research to determine the sources and nature of industrial and domestic pollutants.

(3) Economic and social analysis of water supply and use to determine means of increasing economic efficiency.

(4) Assistance in solving the problem of conflict in water use, including recreation.

(5) Development of improved information retrieval systems.

Most projects supported to date have contributed to these goals. Current research projects dealing with present water conditions are A-017-RI (iron and manganese in water), A-018-RI (yellow organic matter in fresh water) and A-019-RI (trace elements in water). Two projects (A-016-RI and A-023-RI) consider soil properties of value in future reservoir construction, while one project (A-020-RI) is involved with an important phase in the desalination of sea water. A number of projects have naturally dealt with various pollution problems: structure vs. activity (A-021-RI), viral flora (A-025-RI), flocculation of colloids (A-024-RI), bioassay with cultured mammalian cells (A-027-RI), characteristics of fresh-water phytoplankton (B-006-RI), and biochemical oxidation of hydrocarbons in water (B-020-RI).

Although, in the past, much of the research of the Center has been concerned with analytical problems of a chemical or biological nature, it appears that within the next five years the trend will shift somewhat in the direction of planning, social, economic and legal problems as indicated for next year in projects A-032-RI and B-022-RI.

Useful Results From Research Completed This Year

Interesting results were obtained from several projects completed during the year. The work on project A-017-RI showed that sodium hypochlorite can be effectively employed for oxidation of iron and manganese in water and for their subsequent removal by cartridge filtration.

Research on project A-025-RI confirms the suggestion that water may be a route for transmission of avian viruses, from birds (including chickens) possibly to humans. The need for improved methods of monitoring inland water for viral pollution was strongly emphasized and this project will undoubtedly make a major contribution to this end.

Some startling results were found concerning the toxicity of some water pollutants using bioassay with cultured mammalian cells in project A-027-RI. Experimental results suggest that it may be dangerous to overemphasize the banning of some pollutants such as DDT when little is known about alternate pesticides which may be more toxic.

During the year the Center supported five projects, using non-Federal funds entirely, on a one-year basis to enable the investigators to get new research initiated.

Regional Cooperation

The Rhode Island Center worked very closely with the State Water Resources Board and with the New England River Basins Commission and the Director has appeared before both groups to supply information when requested.

The Director of the Rhode Island Center has served as Chairman of the New England Council of Water Center Directors since January 1969, and was elected Secretary of the Northeast Association of Water Resources Research Institute Directors at its meeting on April 14, 1969.

The New England Council spent much time preparing for a conference on "Ecological Considerations in Water Resources Planning and Management" and doing the preliminary work on a regional research project to be submitted under Title II next year.

SOUTH CAROLINA

A. W. Snell

The major current and anticipated water problems for the State of South Carolina include (1) water quantity distribution, (2) water quality preservation, (3) water resources planning, (4) institutional arrangements or water policies, and (5) orderly development of coastal estuaries. Due to the expected increase in industrial development, accelerated urban growth, transition to a more integrated agriculture producing and processing higher valued commodities, increased demand for improved water-based recreation, and encroachment upon the coastal estuaries, each of the water problems stated above is expected to continue to expand.

The Water Resources Research Institute program is planned so as to maintain a balance of project activity seeking answers for the highest priority water problems. Interdisciplinary research is encouraged on the more complex water problems. Close coordination is maintained with State and Federal agencies and the South Carolina Water Resources Advisory committee in the identification of priority problems.

Many individual projects of the Institute will be directly applicable to existing water resources problems. The study of legal problems will assist policy-makers and legislators in defining the most needed statutes and institutional arrangements for water management in South Carolina (B-003-SC). Research on current land use in estuarine areas will be used as an input by the State Task Force on tidelands to develop a comprehensive management plan (B-012-SC). Results from

Institute supported projects will provide increased technical knowledge for design and planning. Removal of impurities can be substantially improved by an addition to the trickling filter effluent (A-012-SC). The computer modeling of limnological parameters for use in predicting water quality should provide additional information needed in water quality control (A-016-SC). Computer models under development will provide flexible and efficient techniques for predicting characteristics of existing or proposed water distribution systems (B-006-SC). A detailed study of the interflow process and its controlling parameters could lead to soil profile modification resulting in faster seepage to the water table and better stream-flow stabilization by reducing contributions during high flows and increasing based flow (B-008-SC).

Completed research provides information applicable to many water resources problems. The popular belief is that those who lower the level of water quality should pay for such action and that the funds should be given to those adversely affected by reduced quality. One study, however, (B-004-SC) concluded that economic efficiency is best served by using the funds collected wherever their productivity is highest. Another study under the same project concluded that many of the ways now used for measuring the benefits to those who use water for recreational purposes result in an over-statement of the economic value. The marginal value rather than the average value of recreation will be necessary if water quality is to be allocated so that water is put to its most valuable use (B-004-SC). Although no induced polarization effects were noted in a study of the geophysical methods of electrical resistivity and electrical induced polarization, it is possible to distinguish the various lithographic units such as soil horizon, bedrock, water saturated overburden, and unsaturated overburden horizons with electrical resistivity measurements (A-011-SC). The amount of DDT accumulated by fish has been determined in relation to the level of contamination in the water. This information is being used to determine restrictions that should be placed on the use of DDT that would contaminate water (A-013-SC). Capabilities gained from operation and testing of the Stanford Watershed model will enable the simulation of probable events on ungaged streams or those with short-term records. The effects of historical or anticipated watershed changes on hydrologic performance of the watershed can be investigated using the model as a tool (A-010-SC). Experimental data to check a mathematical model of transpiration from the root zone to the atmosphere showed transpiration to cycle with a quite regular period and amplitude indicating the doubtful value of using a steady-state model to describe the phenomenon (B-001-SC). Economic data on water use, waste treatment, water pollution and related data in South Carolina manufacturing plants were distributed for use by action agencies (A-002-SC).

The Institute coordinates its programs very closely with State and Federal agencies. The Institute is represented on the South Carolina Water Resources Commission, the South Carolina Pollution Control Authority, and exerts leadership on the Governor's Advisory Committee on Water Resources. Members of the Institute faculty serve on Task Forces for State studies, participate in schools for treatment plant operators and others and serve as consultants in other state-wide capacities. The Councils of the Institute sponsor seminars, discussions, and field trips for students and staff on important water resources activities.

Meetings have been held with Institute Directors of neighboring States and with action agency representatives in developing projects applicable to the State or Region.

The State of South Carolina has and is continuing to make a significant contribution to water resources research. The most significant item during the past year was the appropriation through the Water Resources Commission of State funds to support the Institute. In addition, the Water Resources Commission has been instrumental in bringing together representatives of diverse groups to discuss water resources problems providing a stimulus to water resources research.

SOUTH DAKOTA

John L. Wiersma

Water problems of the State revolve around efficient use of the limited annual precipitation received. Development of an irrigated agriculture is underway. Groundwater sources as well as surface stored water resulting from Missouri River Basin development is bringing forth problems allied with irrigation development. Pollution from agricultural sources, a problem closely allied with eutrophication of prairie lakes, is of extreme interest, resulting in amplification of research. Planning of efficient water use, determination of social implications and inherent political complications of resource development must be solved in order to promote economic stability to the area.

The program of the Institute is focused primarily on immediate research needs. Research on current developed private irrigation is leading the way for determination of proper practices on the anticipated Missouri River water irrigated land. Project A-001 is determining the effect of marginal quality irrigation water on accumulation of salts and alkali in irrigated soils. Project B-004 involves salinity above a water table as affected by rainfall and irrigation. These projects will be instrumental in determining drainage requirements, a key to successful irrigation of many South Dakota soils. Project A-017 is evaluating operation of current irrigation systems, information that can be extrapolated to future developments whereas Project B-009 is making an economic analysis of irrigation systems. Pollution research from agricultural sources is emphasized because quantity control regulations are being formulated for all surface waters. The Institute is meeting the need with several projects. A-025 is studying quality and quantity of runoff from livestock feeding operations and relating this to hydrological and geological considerations. Bacteriological water quality analyses of methods for detecting fecal pollution, Project A-019, is addressed to the problem of developing methods for distinguishing between human and animal sources of pollution. Irrigation waste water and rainfall runoff, carriers of wastes, will receive intensive attention. Degradation of prairie lakes, an inseparable problem from pollution, is receiving major attention. Project B-002 has two phases, dynamics of limnological factors and levels and effects of insecticides. Project B-013 determines the effect of dredging on nutrient levels and biological populations of a lake. Efficient use of rainfall is receiving attention through Project A-018 which is devising a method based on soil-plant-meteorological relationships for more efficient utilization of water and solar energy in crop production. Projects B-008 and B-005, are involved in resource planning to determine the impact of imposing a water quality standard on a live stream. It is the intent of the Advisory Committee to promote added activity in this and social economic areas.

Completed and ongoing research is beginning to solve current problems. A-010 has shown that water losses to sinkholes are essentially in balance with gains to the resurgent springs. This information has made it possible to advise planners that plugging sinkholes may have serious effects on yields from major springs, but will probably not affect recharge of the limestone artesian system beyond the outcrop area. Project A-015 has shown that much more stringent controls in the use of chlorinated hydrocarbon insecticides must be practiced if man is to maintain a quality environment. Results from Project B-002 indicate a concentration of dissolved solids can be expected to occur in many shallow northern prairie lakes under ice cover and thus cause substantial chemical changes during winter months. Project A-017 concludes that the energy-budget approach of estimating consumptive use is a reliable method of soil moisture estimation. Improved methods for enumeration of Streptococcus bovis from ruminant water pollution have been developed by Project A-019. In order to meet water quality standards, planners will need to consider low flow augmentation to offset projected reduction in downstream river flows when extensive groundwater development reduces late year yields, according to results found in Project B-005. Project A-025, studying pollution potential of runoff from livestock feeding operations, is providing guidance for preparing regulations to control pollution from feedlots.

The Institute is becoming recognized as a place to secure information on water resources. Some staff members and the Director, are serving on several State and National committees including one on rural wastes In addition, they are serving on Committees in State and National Reclamation Associations and professional societies. A committee developing a State irrigation guide includes the Director. State standards for "Irrigation Wells" and for "Irrigation Pumping Units" are being developed with aid of the Institure. Various project reports have been useful to special groups such as livestock feeders and growers, lake associations, League of Women Voters, State Legislatures, and Conservancy Districts.

The Mid-Continent Water Research Directors have made it possible for principal investigators in the areas of evapotranspiration and pollution to have region-wide discussion sessions on their problems. This group will be sponsoring a symposium of "Agriculture and Water Quality."

Although the Institute has encountered problems such as obtaining qualified graduate students and an apparent lack of interest in the important socio-economic area, it is felt that progress is being made. The increased support by the State indicates a mutual feeling.

TENNESSEE

Floyd C. Larson, Director

Water Problems

Water problems in Tennessee are concerned primarily with the quality and quantity of ground and surface water. Additional geologic studies of ground water behavior are needed along the Highland Rim and in other areas of ground water deficiency. With respect to impounded waters, there is a need for more basic and applied knowledge of density currents as related to temperature for thermal pollution, stream flow, mathematical models, dissolved oxygen and other water quality parameters. More information is needed on flow augmentation from storage reservoirs as a means of upgrading poor water quality of downstream water bodies. There is concern over continued growth and movement into the TVA reservoirs of Eurasian watermilfoil which interferes with water-based recreation and other water uses. An Asiatic clam has also invaded these reservoirs. It creates a problem to sand and gravel operators as well as to operators of pumping stations where reservoir water is being used.

Flooding of both large and small streams occurs in Tennessee. In the controlled surface water systems, flood damage is minimized by flood routing through the reservoirs. In unregulated systems, however, flood plain zoning plans or other protective devices or systems should be developed and implemented.

Problems may also arise for water front landowners who have property on tributary reservoirs when primary emphasis is placed on flood control and power production. Extreme changes in water levels which occur in the tributary reservoirs are not in the best interest of shoreline development and impedes economic progress. An economic study involving all facets of this problem should be undertaken. Economic analyses of the need for water front industrial sites need to be developed.

Additional research attention is warranted on paper mill effluents, salt coming from a neighboring State, and problems of wastes from cannery, meat, milk and laundry plants. An investigation of the renovation of waste water for reuse would be useful to water users in the State.

Recent reports of legislative committees dealing with water law bills show the need for a thorough economic, technical and legal study (in depth) of the present water laws.

Current Research

Broadly speaking, ongoing projects in FY 1970 in water quality work are listed as follows: A-013-TENN, A-014-TENN, A-019-TENN, B-007-TENN and B-010-TENN. Water quality parameters in physical, chemical and biological terms are collected from Fort Loudoun Reservoir in projects A-013-TENN and A-014-TENN and will show the effects of additional industrial and municipal treatment given in the waste water control system for the City of Knoxville. Project A-019-TENN will continue on the geochemistry of ground water in Skillman Basin, Central Tennessee. This work will add knowledge of the relationship of the quality of precipitation to that found in ground water. Project B-007-TENN relates to water quality studies in that the theoretical and experimental laboratory work gives a further insight to the physical mixing process of fluids. It will be most useful in predicting what effects the introduction of contaminants will have on downstream water quality. Project B-010-TENN will improve techniques for laboratory experiments, design new tests for hydraulic transients, and extend hydraulic transient tests to uniform steady flow conditions. Again, additional knowledge of the hydraulics in a reservoir system has a direct bearing on water quality parameters. Do the contaminants move downstream or upstream under certain operating conditions? The results of this project will be most informative.

Project A-012-TENN deals with fundamental research on isotope effect on the thermodynamics of water. Project A-015-TENN, is concerned with the quantity of surface water in relation to the growth of manufacturing employment in a county. In the future, the research will include the influence of water quality on the location of industry and the role of ground water as a source of industrial water. Project A-018-TENN will study virus removal by several conventional water and waste water treatment processes. In project A-017-TENN existing drought data will be compiled, computerized and analyzed and the information made available for evaluating soil-crop-moisture-fertility situations.

Implementation of Research Results

Results obtained from project A-003-TENN on small reservoir sealing have been used to successfully treat at least six ponds in the State. The Principal Investigator for this project has also made many on-site visits to small ponds and made recommendations for sealing them.

Many inquiries have been received from TVA, the Tennessee Stream Pollution Control Board and others regarding copies of WRRC Technical Bulletin #1. This bulletin contains three years of raw data secured from project A-006-TENN on effects of controlled releases on the physical, chemical and bacteriological characteristics of Fort Loudoun Reservoir.

Other Activies and Accomplishments

The Tennessee Center Director is an active member of the Clean Environment Council of the Greater Knoxville Chamber of Commerce and represents the Council on water resources matters. The Director and principal investigators of P.L. 88-379 projects, through various public and academic involvements, participation in conferences and other activities, strive to promote public education and advance water conservation and management. Increased effort will be made to enlarge matching grant program participation in the State.

TEXAS

J. R. Runkles, Acting Director

During the past year, the Texas Water Plan was released by the Texas Water Development Board. The Texas Water Plan is a comprehensive state-wide plan for the conservation, protection, development, redistribution and administration of the State's water resources to meet the needs for all purposes to the year 2020. The solution of many of the State's water problems is outlined in the Texas Water Plan. The magnitude and complexity of this plan exceeds that of any water plan in existence in the world today or even in the planning stage.

Today, Texas has many water problems involving both quantity and quality of this resource. Groundwater aquifers presently supply about 75% of the water used in Texas. More groundwater is being removed in some areas of the State than is being replaced by natural recharge. By far the bulk of the surface water resource occurs in East Texas while projected needs are great in West Texas and Southwest Texas. Interbasin transfer within the State will be necessary to meet some of the State's anticipated needs. Projected needs for water reveal that the present fresh water supplies from both surface and aquifer sources within the State's borders are not adequate, thus importation will be necessary.

The streams, groundwaters and coastal waters are being used to dispose of waste effluents. Pollution problems are severe in many streams and especially in the bays and estuaries. The extent of groundwater pollution is not adequately known, but it is believed to be serious in many places. Pollution of the water resource from both man's activities and natural sources needs to be abated as rapidly as possible and further pollution prevented. Water quality management is an integral part of water planning for maximum beneficial use of water, maximum reuse of waste water, and to preserve the bays and estuaries.

Water problems associated with implementation of the Texas Water Plan are of considerable magnitude. The problem of physical transfer, storage and conservation of the large quantity of water involved presents a great challenge to our science and technology. The chemical, biological and ecological problems related to the water development plan will need the attention of many scientific disciplines to adequately protect and use this resource. The social, cultural, economic, and institutional problems associated with the proposed water development will require considerable imagination for this solution.

Since the beginning, the Water Resources Institute has directed its activity to many of the critical water problems of the State. Research on the agricultural resources of the State in relation to water development (A-001-TEX) was used in developing the Texas Water Plan. Economic impact of different levels of irrigation on the State's economy (B-005-TEX) was also used in developing the water plan. The economic impact of water impoundment on the surrounding community has been more clearly defined by research of the Institute (B-001-TEX and B-019-TEX). Several analytical models have been developed for investigating selected water resource planning problems. A regional input-output model has been developed and is useful in demonstrating the impact of water resources on a regional economy (A-004-TEX). The pollution of the Houston ship channel was described by an analytical model (A-004-TEX) and is now under intensive analysis as part of the Galveston Bay Study. Specialized optimization techniques have been applied to water quality and water quantity management problems in relation to planning (B-024-TEX).

The irrigated areas of West Texas which is expected to be deficient of water in the future without importation to the region has received considerable research activity of the Institute. The loss of water by evaporation from the soil surface (A-006-TEX) is being investigated as well as possible economic methods of suppression (B-002-TEX). Recharge of playa lake water into the Ogallala groundwater formation is one consideration for the West Texas area. Recharge systems

(B-016-TEX) are being studied in combination with playa lake sediment composition (B-004-TEX) and certain aspects of water quality (B-007-TEX). Treated sewage (B-021-TEX) as a source for recharge is being examined as to its influence on groundwater quality.

During the next five years, the thrust of the research program of the Institute will be to water problems revealed during the development of the water plan and those anticipated in order to effectively implement the Texas Water Plan. Considerable emphasis of the research program will be on economic theory related to cost-benefit assessment of the different aspects of the Texas Water Plan. Operational research on water quality and water quantity problems will receive considerable attention. Water conservation systems of both land and water surfaces will be investigated. Water quality problems associated with pollution abatement and with restoring polluted areas to a productive capacity will receive considerable activity.

The Institute has become involved in public affairs concerning water resources in its role as a unit in a public university. The Director periodically speaks to groups concerning the importance of water resource problems. The Institute has in the past year received a sizable increase in correspondence with questions concerning water resources. All inquiries received a response.

UTAH

Jay M. Bagley, Acting Director

Current and Anticipated Water Problems

Within an arid regional setting, Utah faces a most significant continuing problem in developing and utilizing its water from interstate streams. Although compacts specify entitlements and permit individual states to move forward in their development, there is still a great deal of accommodation required to resolve the interstate perturbations resulting from the development and use of water from a common supply. The interstate problems of allocating and developing interstate waters will be formidable also.

Utah will continue her urban build-up along the narrow band commonly referred to as the Wasatch Front thereby intensifying water quality management problems. Even with secondary treatment of sewage, the effluents of many city treatment plants co-mingle in the Jordan River with the result that quality standards set for that stream are already exceeded. The Great Salt Lake is the ultimate sink for water wasting from this concentration of municipalities and industries along with the agricultural enterprises served by the Bear, Weber, and Jordan Rivers. Large quantities of water find their way into the lake and are evaporated. One of the greatest water challenges of the century will be to (1) reduce these discharges to the Great Salt Lake and transfer them to water deficient areas elsewhere to serve as economic stimuli; (2) at the same time preserve the unique natural aesthetic and recreational attributes of the lake, and (3) encourage the extraction of the vast mineral wealth contained in the brines of the lake.

Principal Research Thrusts Over Next Five Years

In large measure the research thrust of the Utah Center is dictated by the priorities and guidelines being followed by OWRR in the selection of proposals for funding. However, all of the current projects of the Utah Center have direct or indirect application to Utah problems. In the next five years the Utah Center expects to engage in a broad but coherent spectrum of research activity aimed at providing solutions to some of the problems suggested under the general discussion in the previous section. For example, project B-027 should provide guidance and insight into how the state might allocate its entitlement to the Colorado River. Project B-028 will provide a basic model of the Bear River system which can be employed to test alternative schemes for development. Projects B-004, B-009, B-013, and B-025 are directed towards improving methods of describing physical alternatives. Projects A-006, A-007, A-008, and B-010 will provide important keys to specific segments of the water quality management problem.

Use of Research Results

Some of the telemetry developments under Project A-002 are being effectively employed in other research (weather modification, air pollution, water quality, etc.). They are also being used in operational programs of the U. S. Department of Agriculture. The Hydrologic Atlas of Utah developed under B-001 has been enthusiastically received by a variety of state, federal, and private agencies. The Utah Tax Commission is making rather unusual use of the Atlas materials in its appraisal and evaluation procedures.

The Water Resources Division is making more routine use of the analog computer models developed under B-005, B-016, B-017, and B-028 in testing specific alternatives. Also being utilized are results of B-004, B-009, B-015, and A-001 as guidelines to the economic and social value of water.

It is anticipated that results obtained from projects A-003, A-006, and A-008 will assist in the more efficient design and operation of sewage lagoons.

Other Activities and Accomplishments

The significant involvement of Center associates in public affairs continues high. A notable example is the assignment of D. F. Peterson during the past year as director of the Water for Peace Program in the State Department. Many others are serving in various federal, state, local, and professional and scientific organizations as officers and committee members. Center associates continue to be the prime movers and key participants in new academic offerings, institutes, seminars, and workshops having to do with water. As in the past, several associates have been abroad participating in training, research, or consulting activities. Significant contracts for research and training have been negotiated this year with AID.

One of the difficulties encountered in administering the Water Resources Research program has been late notices of proposal acceptances or rejection. However, a new schedule recently provided for FY 1970 should lessen the problem.

The fact that PL 379 does not permit payment of fringe benefits from federal funds is a constant consternation to the University Business Office. This unwarranted provision needs to be changed.

The Utah Center is administered by a council of seven men from various disciplines with one of them acting as chairman. In addition, an advisory committee was recently selected which will facilitate closer correlation between the Center and agencies, schools, industries, and other water-related interests throughout the state.

VERMONT

Thomas W. Dowe, Director

Vermont's Center recognizes problems in quality, quantity, and management of the State's water resources.

As with many other states, sections of Vermont have been subject to periodic shortages of water in the past few years. With increasing demand, these shortages will become frequent unless the state grows more efficient in resource development and utilization. However, efficiency is difficult in the absence of a detailed understanding of the available resources and the processes controlling watershed yield.

Growth has also impelled Vermonters to recognize the possibility of pollution of its waters. Lake Champlain, one of the largest and deepest lakes in the United States, is particularly subject to the danger of pollution. Dangers include petroleum contamination, industrial waste, and a possibility of excessive eutrophication. In this area again, lack of knowledge is a great problem. Scientists and government planners must know the physical, chemical and biological properties of a body of water before they can assess the possibilities of pollution and plan against them.

The quality and quantity of water resources in a state also depend in great part upon the use and management of the lands and forests in the various watersheds. Yet little is known of the specific effects of various management practices and uses.

To solve the problem of water quality, quantity, and management which the Center has recognized, programs have been planned in Lake Studies, Watershed Studies, and Surface and Ground Water Supplies. Related to the Lake Studies, and considered here with them, although they are separate projects, are studies on the chemical characteristics of precipitation in the Champlain Valley, the Lake Champlain phytoplankton, and the bottom sediments of the lake.

Lake Studies

Limnology studies are designed to analyze the physical, biological, and chemical aspects of Lake Champlain and other lakes in the state. Before their inception, virtually nothing was known of Lake Champlain's characteristics.

The specific purposes of phase one of the study (A-001) were to ascertain the nature of several water masses in the state, identify the biota, and evaluate the hydrologic dynamics of the lake and its watershed. Several distinct water masses have been identified, and the researchers are developing an understanding of their meaning. They've also analyzed the general quality of the lake and pinpointed possible problem areas. The major species of zooplankton have been identified and seasonal distribution of certain groups studied. Researchers have also identified the bottom fauna from most shallow bays and are now starting studies for deep water fauna. In addition, they have made estimates of the water budget of the lake.

With the State Department of Water Resources, researchers are making an intensive study of a part of the lake adjacent to the proposed site for a nuclear power plant. Another cooperative project is a study of Lake Memphremagog, an international body of water.

An advanced class in limnology has conducted a survey of a potential water reservoir for the city of Winooski under their Model Cities Program.

The second phase of the study will include an analysis of the nutrient input of the lake and other specific projects to aid in understanding ecology of the lake for proper management.

Related Projects

Phytoplankton (A-009)

The normal pattern of recurring successional changes of algae has now been established. Algae which are known indicators of water conditions are currently being studied in more detail.

Bottom Sediments (A-003)

Analysis of bottom sediments helps in evaluating the present quality of Lake Champlain. Wastes are deposited there, and the sediments also reflect the nature of benthonic organisms. In first stages of the program, the investigators concentrated on surface sediments; later they will study the depth sediments.

Glacial Biology of the Lake Champlain Valley (A-006)

Studying approximately three-fourths of the Champlain Valley has provided extensive information on the amount and location of ground water supplies, sand and gravel resources, and areas where erosion could be a problem. The information has also been used in evaluating the success of an erosion control program instituted by the SCS and Corps of Engineers on the Winooski River in the 1930's.

Precipitation (A-007)

This project was designed to indicate the significance of precipitation as a cleansing and enriching agent in the Champlain Valley.

Watersheds

To eliminate present duplication and lack of coordination in watershed administration, investigators are comparing various means of administration. Other researchers are attempting to determine the economic impact of certain recreation facilities in selected river valleys.

Engineers are studying the parameterization of observed hydrographs as a means of understanding runoff phenomena from small watersheds (A-008).

Surface and Groundwater

Aims under this program were to investigate the physical processes of the hydrologic cycle, analyze the existing data pertinent to the quantity and quality of Vermont water resources, survey and assess the largely unexplored ground water resource of the state, and improve the means of small supply purification. Progress on some of these aims has already been reported under previous headings e.g. Glacial Biology.

Academic Cooperation and Student Involvement

Funds from PL 88-379 have enabled the Vermont Center to bring together scientists from the colleges of agriculture and home economics, arts and sciences, technology, and medicine, and to provide research opportunities for graduate students.

VIRGINIA

William R. Walker, Director

Although Virginia has an average of 43 inches of rain per year, water problems of both quantity and quality are very prevalent. Research aimed at providing information related to both short and long range objectives are a necessity if effective utilization of its water resources is to contribute to a strong state economy and at the same time provide a quality environment.

In an effort to identify many of the critical water problems facing the state, a series of meetings were held with state agency leaders and faculty members from a variety of disciplines. It became increasingly evident to the participants that many of the problems could not be solved independently and that the sum of the solutions from separate disciplines is not likely to be the solution of the whole.

Much of the information which research can provide is viewed by state agency personnel in terms of technical and economic needs, the legal and institutional restraints appearing less obvious. Awareness of the deficiencies in the field of sociology and psychology as related to water resources is practically nonexistent.

The discussions disclosed many areas needing immediate research such as: A satisfactory temperature standard for state waters, pollution from combined sewers, methodology for investigating fish kills, compatibility of oyster beds with waste water outfalls, improved criteria for operation of waste stabilization ponds, agricultural pollution, seawater encroachment in coastal areas, a statistically significant system for monitoring and sampling, impact of reservoir drawdowns on recreation and on regional economy, conjunctive water use in water resources planning, resource potential of wetlands and marshes, relation of water resources to economic growth, evaluation of recreation and wildlife other than by market pricing, and water pricing as a method for allocating water use.

The list does not include all of the areas which need research, yet it will take a significant financial input on a sustained basis by Virginia to close the information gap for just the research needs enumerated.

The Center's current research program gives increased emphasis to the problem areas. Project B-009-VA deals with the effects of reservoir operating policy on recreational benefits, B-017-VA is concerned with the effects of heated waste waters upon microbial communities, and B-025-VA is analyzing and evaluating the Virginia water resource administrative agencies. Project A-032-VA involves the development of an electrochemical process for more economical regeneration of carbon used in tertiary treatment. A-031-VA is a pre-impoundment study of the North Anna River prior to receiving discharges from a thermal reactor. B-021-VA is designed to predict surface temperature variations and evaporation losses for impoundments, and A-023-VA is developing a method for measuring underground storage.

Some of the research completed to date has found immediate application. An example is Project A-008-VA which was concerned with the statutory and case law dealing with water resources in the Commonwealth. The first printing of the report (500 copies) was exhausted within six months. The demand is such that a second printing is in press. The city attorney of Harrisonburg offered this comment: "I would like to take the opportunity to compliment you for an excellent and much needed publication."

Center Involvement in Public Affairs

Liaison between the Center and water agencies, state and federal, is through personal contacts by the Director. The director participates in citizen advisory groups to discuss the part research might play in developing the information necessary for good policy decisions. Membership on state legislative advisory groups enables the director to contribute in the formation of legislation related to disposal of solid wastes affecting water and streams, and the licensing of water and waste treatment plant operators. A seminar on combined sewers was sponsored to learn first hand the results of ongoing research, to determine research needs not being met and to promote understanding between interested researchers and cities with problems needing immediate attention. The Center also sponsored a three-day short course on the economics of air and water pollution for engineers and administrators.

Center Involvement in Academic Affairs

The Center recently published a bulletin, "Water Resources Research Interests in Virginia." This inventory of staff capabilities at all the institutions of higher learning in Virginia enables the Center to readily solicit the best talents of the Commonwealth for research on a specific problem.

The director's input into university committees such as the one on Patents and Proprietary Rights helps to encourage a fair patent policy for the university and the researcher.

A memorandum of understanding was executed by the Center and ARS, U. S. Department of Agriculture to provide a vehicle for more cooperative research on campus.

WASHINGTON

Allen F. Agnew, Director

The State of Washington Water Research Center is now concluding a second major group of studies for the Washington Department of Water Resources. These studies, although only indirectly supported by OWRR, were made possible by the establishment and continued backing of the Center by OWRR under PL 88-379. We have a strong feeling that studies such as we are doing should be interdisciplinary, and have been attempting to make them so. Many of the involved faculty have worked together off and on now for nearly four years.

A truly satisfactory interdisciplinary approach requires essentially that at every decision-making step every alternative and consequence be understood. This incredible requirement is further complicated since, if all consequences are to be understood, all factors must be considered. Unfortunately, many factors are not reduceable to common terms. It is difficult to equate BOD reduction, for example, with the value of scenery. The decisions, then, in fact quite often become political.

Decisions on water resource developments are made daily--too often without considering the overall effect or, even that there are valid alternatives. This is not due to the ineptness of state and federal agencies. In most cases, particularly at the state level, it is due to the simple fact that they are grossly overworked and inadequately funded. Unfortunately water resources agencies thus barely have time to keep up with their "housekeeping" duties and little or no time for planning. Since the major effort of future project construction will probably continue to be in the federal sphere--if the state has any expectations of influencing the federal forces, and it should, it must be prepared to critically evaluate the federal plans in line with its own. Modern tools developed to aid them in the planning function will be a tremendous asset to their operations.

Thus, the university-associated water research centers have the opportunity to be of tremendous service to the state water resources planning agencies. Through an integration of the multidisciplinary expertise available on the campuses we can offer objective research and consultation. In the state of Washington we have been attempting to work very closely with the Department of Water Resources. Through funds from OWRR and from state and private sources we have thus far been studying as many of the individual factors (water quality, recreation, groundwater, etc.) as possible and are planning to start our first systems analysis of a major area of the state. In this study computerized models of the hydrology, river hydraulics, economic interactions, water quality, recreation, and irrigation will be developed individually. When completed they will be integrated to form an operational model by which the effects of various alternative operating schemes can be evaluated.

It is clearly understood that not all of the relevant factors can be incorporated into a systems model. However, it is felt that the procedure we contemplate will offer a rational method by which the planners can compare various alternatives. With the successful completion of this first stage, models for other areas will be similarly developed and tied in. This procedure will eventually give the Department of Water Resources a major tool for evaluating any proposed plan.

Many of the allotment projects sponsored through the Center will have direct application in the systems study either as direct input or as an indirect aid in evaluating alternatives; a few are discussed here. One of the factors, for example, which is as yet not quantifiable for direct inclusion is the effect on waterfowl reproduction of the development of a water resource. Project A-005-WASH, "Some Effects of Water Impoundments on Waterfowl Populations and Reproduction on the Snake River," by Dr. Irven O. Buss has been attempting to fill this knowledge gap. Project A-003-WASH, "Simulation of a Water Resource System," by Dr. D. E. Bevan and Dr. G. J. Paulik, however, has shown that many of the effects of flow and water quality can be simulated to show the effect on fish.

Several projects deal directly with the stochastic nature of runoff and will be incorporated into the system model with only slight modification. Project A-020-WASH, "Serial Correlation in Annual Stream Runoff," by Prof. T. Campbell, Project A-028-WASH, "Runoff Generation as a Function of Precipitation and Watershed Characteristics," by Prof. J. Gladwell and Project A-022-WASH, "Methods of Analysis and Determination of Effects of Alternative Uses of Forested Lands on Streamflow," by Dr. S. Gessel are typical of those underway or recently completed.

A project dealing specifically with the water requirements for irrigation use will be of particular importance to economic analysis: Project A-025-WASH, "Maximizing Productivity of Water Used for Irrigation of Agricultural Lands," by Dr. N. Whittlesey and Dr. W. Butcher. In addition, the physical and economic effect of water quality control will be included as a result of studies sponsored by the Department of Water Resources.

Future activities of the Washington Water Research Center will show an increased emphasis on public communication. Although seminars and conferences have been and will continue to be sponsored on campuses, greater effort will be made to involve non-university people in these activities. It is expected that these functions will be of interest to both technical and non-technical people interested in the water resources of the state and region. There will also be renewed interest in establishing close ties with the decision makers of government at all levels in order to open the lines of communication which are all too easily closed. Finally, a regular newsletter will be published in which water resource problems of the area will be discussed.

WEST VIRGINIA

Chester L. Dodson, Director

The water-resource problems of West Virginia are chiefly related to flow characteristics of streams and to water quality. Space and time distribution of precipitation, mature physiography expressed by rugged and steep topography, and impermeable bedrock and shallow soil relate to the flow characteristics. The fundamental characteristics are extremes of flow caused by rapid runoff.

Water quality is basically related to the flow extremes and to mine, industrial, municipal, and agricultural effluents. Acid mine water causes an outstanding example of water pollution but other causes of water pollution are equally significant. A problem that is becoming increasingly significant is heat pollution caused by steam electric stations. Using coal to generate electricity is vital to the future economy of West Virginia, but keeping the adverse effects of cooling to a minimum will require optimum management of the water resources.

Lack of knowledge can be considered the greatest of all water problems. The lack ranges across the unavailability of basic data, the unknown ecologic effects of water quality, the social effects of water-resource development, and on to the lack of trained water-resources manpower. Much new knowledge must be gained if the state is to obtain the greatest benefits from its water resources.

Main Thrust Toward Problem Solving

Although not so limited, the main thrust of the Water Research Institute has been, and during the next five years will be, toward solving water-quality problems. Although partly incidentally, most of the effort has been related to acid mine water. In the future, more research will be related to thermal quality and socioeconomic effects.

Accomplishment-using results from a given project cannot be totally and specifically limited, identified, or defined because, among other things, the future cannot be known, but some examples can be given. Results from completed Project A-001-WVA will aid in using knowledge of the effects of acid mine water on fish to establish more rational water-quality standards and perhaps to establish recreational fisheries in streams containing low-quality water. On-going Projects A-016-WVA and A-017-WVA continue the studies begun under A-001-WVA and are expected to give more positive and useful knowledge. Completed Projects A-002-WVA and A-014-WVA and on-going Project A-018-WVA have yielded, and are expected to yield, knowledge of the microbiology of mixtures of acid mine water and sewage that can be of far-reaching significance in management of water quality and perhaps will lead to new treatment methods.

Completed Research Results Being Used

Most project completions have been so recent and so few reports have been published that use of the research results has barely begun. The largest use has been in planning new projects. Methodology related to runoff, which was developed by Dr. Vulli L. Gupta on Project A-003-WVA, is receiving widespread interest and is being used by others. Results of chemical analyses done as part of Project A-008-WVA were used in planning a community water system and saved about a year of planning time. Results from Project A-006-WVA are aiding in prediction of precipitation in remote areas and design of engineering structures, but the impact of the study will follow sometime after distribution of the published report.

Other Activities and Accomplishments

The Water Research Institute is becoming the focus for new water-resource knowledge in the state. A report is being prepared that can serve as a basic guideline for formulating water-resource policy by State Government. The Institute continues being the coordinator of water-resources research at the University.

The Institute, in the person of the Director, is furnishing scientific information needed for formulating and demonstrating to the public the need for a West Virginia water-rights law. During FY 1969, the Director attended meetings of the Legislative Committee that was considering a law.

An attitudinal problem exists not only on the University Campus, but, also, nationally. This is the attitude toward PL 88-379 funding as just another grant or contract and not as support of an institutional system of water-research institutes in the same way as the agricultural experiment stations are. On campus, the problem is being met by continually emphasizing to the University administration that the allotment program is a perpetual institution and should be considered different from grants and contracts.

The institutes of West Virginia, Ohio, and Pennsylvania continued their close cooperation and coordination during FY 1969.

The statewide advisory board of the Institute held its first formal meeting in March 1969.

State direct and indirect financial support during FY 1969 was about $50,000. State agencies, especially the Water Resources Division of the Department of Natural Resources, furnished all requested aid, data, and resources.

WISCONSIN

Gerard A. Rohlich, Director

High on the list of the Wisconsin Water Resources Center's priorities is consideration of the factors causing the eutrophication of lakes and the possibilities for improving technology, institutions, and policies for water quality management. Attention is also being given to determining the effects on water-related resources, of the disposal of waste products and of the use of pesticides in the environment. Several of these investigations will provide background information for the development of the state's water plan. The Center's program encourages interdisciplinary participation on research in priority areas at public institutions throughout the state.

The Center is now sponsoring several projects dealing with eutrophication. Support for the program comes from a number of federal and state agencies, especially the Federal Water Pollution Control Administration and the Office of Water Resources Research (B-020, B-022, A-014, A-017 and A-020). Emphasis is upon understanding the process and developing remedial measures within a multi-disciplinary framework. Projects have been awarded to investigators at a number of different universities within the state.

Another major research effort is focused upon the technical and institutional aspects of water quality management. Using the Wisconsin River Basin as a case study area, an interdisciplinary team of engineers, economists, political scientists, lawyers, and planners have initiated a program of studies aimed at: a) understanding the technical opportunities for managing water quality in an economical fashion within the region, and b) defining the legal, administrative, and fiscal arrangements required to realize such economies (C-1228).

The Center's program encourages interdisciplinary participation on research in priority areas at public institutions throughout the state.

Implicit in the Center's research activities is the responsibility to supply information on research findings. The Water Resources Scientific Information Center has designated the University and the Water Resources Center as a Center of Competence in Eutrophication Information. On the recommendation of the Joint Government-Industry Task Force on Eutrophication, these services have been substantially enlarged. Additional emphasis is placed on providing water resources reference literature on a statewide basis.

Some of the early projects supported by the Water Resources Research Act served as a basis for two of the major research programs underway in Wisconsin. As a result of the early investigations (A-001-WIS, A-002-WIS, A-003-WIS, A-004-WIS and A-011-WIS), the broad scale eutrophication research and information program now underway was developed. Similarly, the preliminary studies supported on river basin planning (A-009-WIS) have evolved into a broad interdisciplinary effort with close liaison with industry, state agencies, and communities within the Wisconsin River Basin which covers one-third of the state.

As an outgrowth of two allotment projects for studies (A-011 and A-019) on Lake Butte des Morts, the faculty at the Wisconsin State University at Oshkosh have formed a multi-disciplinary group to study lake environments and the university has created a Limnology Laboratory to facilitate the effort. Concurrently, the project (A-023-WIS), granted last year at Wisconsin State University-Superior, encourages similar action by the university when it established the Center for Lake Superior Environmental Studies to support interdisciplinary efforts there. Superior's research program has been strengthened through acquisition of a used, 40-foot launch from excess government property which was possible because of the University's activity under the Water Resources Research Act.

The state's flood plain and shoreland management and protection program has been assisted significantly by the efforts of investigators on project B-022-WIS. This in turn led to a contract between the Water Resources Council and members of the project to prepare a report on the legal aspects of flood plain regulation. One member of the initial study has become chief of water resources planning section of the State Department of Natural Resources.

Professor Gerard A. Rohlich, Director of the Center, was elected Secretary of the Natural Resources Board for the state and was appointed to the Environmental Health Sciences Advisory Committee of the National Institute of Health. Also, the director has continued as a member of the Board of Directors of the University Council on Water Resources and as Director of the Institute for Environmental Studies at the University of Wisconsin.

Among his other activities, Professor Irving K. Fox, Associate Director, was a member of the United Nations Panel in Vienna, Austria on international water resources development and is a continuing member of the Research Advisory Council of the Wisconsin Department of Natural Resources. He was recently elected Chairman of the Department of Urban and Regional Planning at the University of Wisconsin. Professor Fox is a consultant to the National Water Commission and was a member of the Board of Consultants of the San Francisco Bay-Delta Water Quality Control Program Study of the State of California.

During the past year, the water resources research activity ties between the state water agencies and the university community have been strengthened under the Joint Agency-Water Resources Research and Data Collection Program.

WYOMING

Paul A. Rechard, Director

The Wyoming Water Resources Research Institute was established at the University of Wyoming in the Fall of 1964 for the purposes of coordinating water resources activities within the University and accomplishing water resources research supported directly by funds allocated to the Institute.

Administratively the Institute is a division of the Wyoming Natural Resources Research Institute of the College of Engineering and it operates under policies established by a Water Resources Panel of the University. Members of the Panel are appointed from each of the seven Colleges of the University and serve as a head of a unit of the Institute in their respective Colleges. In addition, representatives of Wyoming State Agencies with major water resources interest serve as Associate Members of the Panel.

The Panel has chosen to utilize the funds available under the Annual Allotment for an interdisciplinary project entitled "Water Resource Operations Study." The purpose of the research is to learn more about the relationships among the many kinds and aspects of water resource operations. Because there are so many ramifications to such a study, the Institute had, as initial objectives, studies to find:

(a) The criteria that might best apply to water resource planning in Wyoming. That is, how might the State of Wyoming best measure the values of various alternative uses (or non-uses) of water. As a study area, the initial investigation will look at the problems of transmountain diversion from the Green River to the Platte River Basins in Wyoming.

(b) Ways and means of utilizing the readings from field instruments by more than one discipline. Too often it is found that an instrument is installed for a single purpose whereas, if consultation and discussion with someone in another discipline had taken place, that same instrument could serve many other purposes. The problems of operating instruments in remote locations is also being studied.

(c) With the possibilities of weather modification becoming operational in a few years, the Institute chose to investigate the possible legal and engineering impacts of the artificial snow-pack augmentation program. The University of Wyoming, through the Natural Resources Research Institute of the College of Engineering, has an active research program on snow-pack augmentation underway at the present time. The impact of this work was the subject studied by the Institute and a project completion report on the legal phase was published in the Land and Water Law Review, Volume II, Number 2, pages 273-319. A reprint of the article, together with a supplement prepared by the author, was published as Water Resources Series No. 11.

(d) The interrelationships of water quality and water utilization will replace the study of the impacts of snow-pack augmentation starting in FY 1970. It is planned to initially study the effects that recreational use of water has on the water quality and, in turn, the effects of water quality on recreational use.

(e) As an overview of the entire water resource operations study and utilizing the data and experience of the other detailed aspects, such as items (a)-(d) above, principles of analysis of water resource operations will be developed.

The Institute has published fourteen reports in its Water Resources Series, four Annual Reports, four reports dealing with State Water Planning in Wyoming, and one general information report on Wyoming's weather. Three additional reports have been processed through the College of Agriculture and seven issues of the Land and Water Law Review of the College of Law. Eighteen advanced degree theses have resulted from support by the Institute.

The Institute is deeply committed to utilizing the major portion of the funds for the support of undergraduate and graduate students at the University. To date, in the neighborhood of 200 students have received some measure of support through the Annual Allotment Program of the Office of Water Resources Research. It is critical to the operation of the Institute that the Annual Allotment continue to be provided, and indeed, due to the cost of doing business spiral, the amount of funding should be increased.

The University of Wyoming also has obtained two matching grant projects under Section 101 of PL 88-379. The first matching grant resulted in a report entitled "The Effects of Varying Land and Water Use on Streamflow Regimen" and was supported in part by the City of Laramie and the University. The other study entitled "The Value of the Game and Fish Resources in Relation to the Future Utilization of the Water of the Green River Drainage in Wyoming" is now underway and is being partially supported by the Wyoming Game and Fish Commission and the University.

The University has submitted four proposals for funding under Title II provisions of PL 88-379. However, none of these proposals has received support.

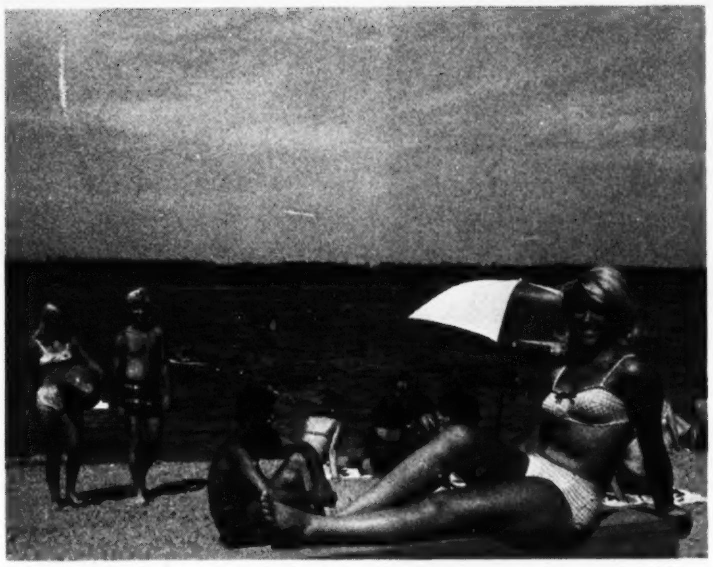
The Wyoming Water Resources Research Institute hopes to become even more active in the water resource program at the University as the years go on. The research underway, it is believed, is applicable to the current problems facing the state and nation, and a measure of coordination of effort is being accomplished.

The demand for water-based recreation is increasing; recreation, esthetics and fish and wildlife values are being given more consideration in water resources planning.

Big Spring State Park in Missouri is popular with people from the urban areas. Photo by Walker-Missouri Tourism

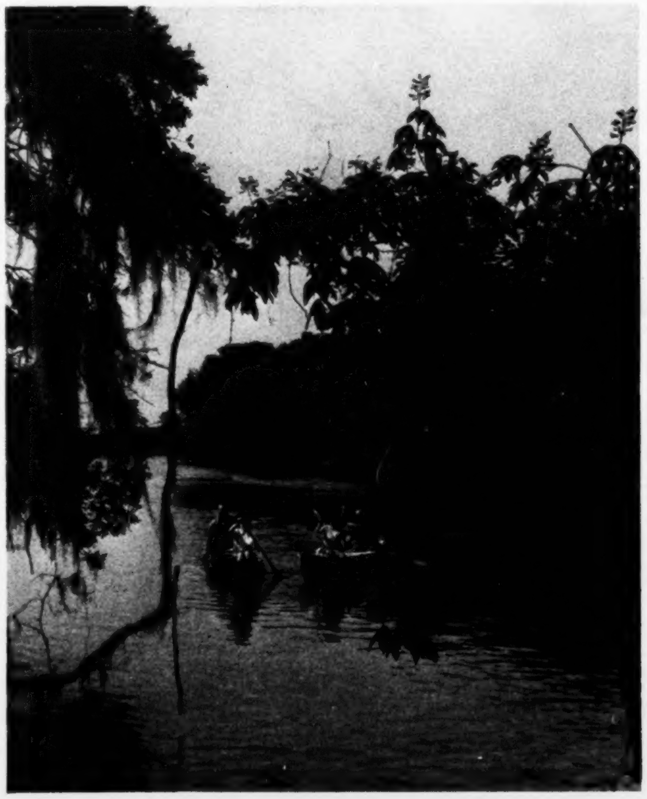
A limit-catch of large mouth bass in 45 minutes, temperature 20°F, January 1968. Old strip mined area behind the Hot Water Arm of Thomas Hill Reservoir (Project A-020-MO). Photo by Arthur Witt, Jr.

Many beautiful gorges and waterfalls around Ithaca, New York provide spectator recreation more satisfying to many than active water sports. Photo courtesy New York State College of Agriculture at Cornell State University



Pomme de Terre reservoir in southwest Missouri has its attractions. Photo by Walker-Missouri Tourism

The many freshwater lakes and streams of the "Sunshine State" offer opportunities for fishing with a cane pole or rod and reel. This photo by the Florida News Bureau shows two people recreating on a section of Marion Creek, Northwest Polk County, Florida.



Canoeing on the placid Wacissa River, Florida. Photo, courtesy Florida Development Commission

Canoeing on a white-water section of the St. Croix River in Minnesota. Photo, courtesy Minnesota Water Resources Research Center

Water fowl hunting is a major sport that extends the season of water for recreation. Photo by Don Woolridge-Missouri Department of Conservation

Hearings were held this past summer by the Oregon Environmental Quality Commission to establish standards for the North Umpqua River in the Cascade Mountains. Reaches such as this provide some of the most famous trout fishing in the nation. Photo, courtesy Oregon Water Resources Research Institute

APPENDIX A

OFFICE OF WATER RESOURCES RESEARCH

ALLOTMENTS AND DISBURSEMENTS TO STATE INSTITUTES

Annual Allotment Program - Fiscal Year 1969

(1) State	(2) Amount of FY 1969[1/] Annual Allotment Agreement	(3) Disbursed to State as of[2/] June 30, 1969	(4) Unpaid Obligations[3/] and Commitments of State Institute as of June 30, 1969
Alabama	$100,000.00	$100,000.00	$ -
Alaska	100,000.00	100,000.00	-
Arizona	100,000.00	100,000.00	-
Arkansas	100,000.00	-	100,000.00
California	100,000.00	100,000.00	-
Colorado	100,000.00	100,000.00	-
Connecticut	100,000.00	100,000.00	-
Delaware	100,000.00	100,000.00	-
Florida	100,000.00	100,000.00	-
Georgia	100,000.00	98,000.00	2,000.00
Hawaii	100,000.00	55,000.00	45,000.00
Idaho	100,000.00	100,000.00	-
Illinois	100,000.00	100,000.00	-
Indiana	100,000.00	100,000.00	-
Iowa	100,000.00	100,000.00	-
Kansas	100,000.00	100,000.00	-
Kentucky	100,000.00	100,000.00	-
Louisiana	100,000.00	100,000.00	-
Maine	100,000.00	100,000.00	-
Maryland	100,000.00	100,000.00	-
Massachusetts	100,000.00	100,000.00	-
Michigan	100,000.00	100,000.00	-
Minnesota	100,000.00	100,000.00	-
Mississippi	100,000.00	100,000.00	-
Missouri	100,000.00	100,000.00	-
Montana	100,000.00	100,000.00	-
Nebraska	100,000.00	100,000.00	-
Nevada	100,000.00	100,000.00	-
New Hampshire	100,000.00	100,000.00	-
New Jersey	100,000.00	100,000.00	-
New Mexico	100,000.00	100,000.00	-
New York	100,000.00	100,000.00	-
North Carolina	100,000.00	100,000.00	-
North Dakota	100,000.00	100,000.00	-
Ohio	100,000.00	98,500.00	1,500.00

(1) State	(2) Amount of FY 1969[1] Annual Allotment Agreement	(3) Disbursed to State as of[2] June 30, 1969	(4) Unpaid Obligations[3] and Commitments of State Institute as of June 30, 1969
Oklahoma	$100,000.00	$100,000.00	$ -
Oregon	100,000.00	100,000.00	-
Pennsylvania	100,000.00	100,000.00	-
Puerto Rico	100,000.00	100,000.00	-
Rhode Island	100,000.00	100,000.00	-
South Carolina	100,000.00	100,000.00	-
South Dakota	100,000.00	100,000.00	-
Tennessee	100,000.00	100,000.00	-
Texas	100,000.00	100,000.00	-
Utah	100,000.00	100,000.00	-
Vermont	100,000.00	100,000.00	-
Virginia	100,000.00	100,000.00	-
Washington	100,000.00	100,000.00	-
West Virginia	100,000.00	100,000.00	-
Wisconsin	100,000.00	100,000.00	-
Wyoming	100,000.00	100,000.00	-
TOTAL	$5,100,000.00	$4,951,500.00[4]	$ 148,500[4]

[1] In all cases, approved State institute programs and related budgets were equal to the F Y 1969 Annual Allotment.

[2] Column (3) shows the actual cash paid out by the U.S. Treasury as of June 30, 1969, to the State institutes in response to approved requests for payment. To minimize end-of-quarter cash balances, advances of funds to grantees are in amounts estimated by the State institutes to be required to liquidate due and payable obligations in the ensuing quarter.

[3] Column (4) reflects the amount not disbursed to the State institutes as of June 30, 1969, against the $100,000 allotment, but subsequently needed by the institutes to meet liabilities and anticipated maturing obligations incurred for the Fiscal Year 1969 annual allotment program. (See 4/ below.)

[4] Of the total annual allotment funds available in Fiscal Year 1969, total disbursements or payments to the State institutes by September 30, 1969 had increased to a total of $5,098,500.00 (99.97% of obligational authority) leaving $1,500.00 remaining to be paid out.

APPENDIX B

OFFICE OF WATER RESOURCES RESEARCH

GRANTS AND DISBURSEMENTS TO STATE INSTITUTES

Matching Grant Program - Fiscal Year 1969

State	Amount of Grant(s)[1]	Amount Disbursed to Institutes in Fiscal Year 1969[2]
Alabama	$177,888	$110,649.00
Arizona	82,950	22,500.00
Arkansas	24,692	-
California	72,955	30,878.00
Colorado	237,470	122,374.00
Delaware	25,800	9,037.00
Georgia	79,464	14,600.00
Hawaii	42,650	29,775.00
Idaho	23,973	7,353.00
Illinois	216,516	82,307.50
Indiana	58,147	13,205.00
Iowa	9,000	4,700.00
Kansas	14,165	2,550.00
Kentucky	48,082	23,774.88
Maryland	76,657	25,257.00
Massachusetts	231,430	85,425.00
Minnesota	115,436	26,799.00
Missouri	12,026	4,978.00
Montana	125,950	32,565.00
Nevada	83,600	49,000.00
New Jersey	17,540	17,540.00
New Mexico	67,596	67,596.00
New York	64,820	20,000.00
North Carolina	291,238	68,151.00
Ohio	30,000	21,400.00
Oklahoma	64,490	26,000.00
Oregon	116,712	51,025.00
Pennsylvania	29,616	15,745.00
Rhode Island	22,450	15,780.00
South Carolina	36,675	11,263.57
South Dakota	61,800	5,000.00
Tennessee	14,297	8,215.00
Texas	110,113	35,654.00
Utah	119,550	45,940.00
Washington	36,750	3,000.00
Wisconsin	157,502	47,425.00
TOTAL	$3,000,000	$1,157,461.95[3]

1/ This column shows Federal support only; non-Federal matching funds are not included.

2/ This column reflects the total cash paid out by the U.S. Treasury as to June 30, 1969, to State institutes in response to approved requests for payment. In accordance with Treasury Department general policy, advances of money to grantees are the amounts estimated to be required to liquidate obligations in the ensuing quarter in accordance with the approved program.

The time period during which a matching grant agreement is effective extends over the entire time during which project activity is scheduled, usually more than one fiscal year. Thus, the beginning and ending dates specified in a matching grant agreement do not necessarily coincide with the beginning (July 1) or ending (June 30) dates of a fiscal year.

3/ As of September 30, 1969 total disbursements of $1,389,477.10 had been made to State institutes for matching grants approved in fiscal year 1969.

APPENDIX C

OFFICE OF WATER RESOURCES RESEARCH

CONTRACT AND GRANT AWARDS AND DISBURSEMENTS

Title II Program - Fiscal Year 1969

Project Number	Organization	Amount of Agreement	Disbursements in FY 1969
C-1032	Kansas State University	$ 31,694	$ 15,523.13
C-1196	Cornell University	29,950	-
C-1282	Univ. of Kentucky Res. Foundation	44,489	-
C-1290	Hydronautics, Inc.	61,000	50,476,10
C-1314	Antioch College	31,548	10,459.81
C-1318	Union College	11,732	9,000.00
C-1321	Stanford University	39,716	-
C-1323	Georgia Institute of Technology	78,400	43,300.00
C-1337	University of Nevada	55,000	43,150.00
C-1339	General Electric Company - TEMPO	67,400	31,272.40
C-1357	George Washington University	48,697	9,315.26
C-1361	New Mexico State University	46,680	35,045.75
C-1370	Booz, Allen and Hamilton, Inc.	71,700	25,176.00
C-1377	Texas Water Development Board	100,000	80,051.23
C-1388	Temple University	7,777	-
C-1396	Hittman Associates, Inc.	128,819	105,721.26
C-1401	University of Maryland	75,000	-
C-1410	Environmental Dynamics, Inc.	88,934	25,000.00
C-1414	Surveys and Research Corporation	47,235	35,555.52
C-1415	Arthur D. Little, Inc.	228,906	65,867.42
C-1428	Virginia Institute of Marine Science	15,225	-
C-1443	Montana State University	31,893	6,395.00
C-1469	Abt Associates, Inc.	95,137	80,866.45
C-1477	Water Resources Engineers, Inc.	75,800	17,580.00
C-1484	Rensselaer Polytechnic Institute	40,000	34,000.00
C-1495	Massachusetts Institute of Technology	28,000	21,000.00
C-1496	Engineering-Science, Inc.	75,000	38,542.71
C-1511	Cyrus Wm. Rice and Company	76,648	65,194.19
C-1397	Hittman Associates, Inc.	84,362	56,850.41
C-1536	American Society of Civil Engineers	84,400	-
C-1537	Texas Tech/High Plains	98,578	41,500.00
	TOTAL	$1,999,720	$946,842.64 1/

1/ As of September 30, 1969 total disbursements of $ 1,358,045.23 had been made to Title II grantees and contractors for awards approved in fiscal year 1969 .

APPENDIX D

OFFICE OF WATER RESOURCES RESEARCH (OWRR)

WATER RESOURCES SCIENTIFIC INFORMATION CENTER (WRSIC)

Fiscal Year 1969 Expenses by Object Classification

Personnel Compensation and Benefits	$104,188
Travel and Transportation	2,451
Rent, Communications, and Utilities	424
Printing and Reproduction	15,383
Other Services, Including Contracts[1]	264,694
Supplies and Materials	722
Equipment	2,292
Grants[1]	96,958
TOTAL	$487,112

Note: Expenses of OWRR's Water Resources Scientific Information Center include costs of systems development, water resources research catalog preparation, augmenting the information base of water resources abstracts relating to significant water resources published and unpublished documents, making document announcement services available to the water resources community, and related technical information center activities.

[1] Includes contracts, grants, or fund advances to organizations providing information base input, information base processing and output, and system study services to WRSIC.

APPENDIX E

OFFICE OF WATER RESOURCES RESEARCH (OWRR)

Fiscal Year 1969 - Program Administration Expenses By Object Classification

Personnel Compensation and Benefits	$476,786
Travel and Transportation	12,581
Rent, Communications, and Utilities	15,164
Printing and Reproduction	9,538
Other Services, Including Contracts[1/]	44,336
Supplies and Materials	4,553
Equipment	3,963
TOTAL	$566,921

Note: Expenses of the Office of Water Resources Research include costs of developing the program and establishing program priorities; reviewing, analyzing and selecting research project proposals for support; coordinating research activities; preparing state-of-the-art studies; advising research centers relative to research needs; monitoring progress and accomplishments under approved research grants and contracts; as well as for administrative and housekeeping functions.

1/ Includes contracts to obtain advisory assistance to program management and for support of organizations providing housekeeping and related services to OWRR.

APPENDIX F

OFFICE OF WATER RESOURCES RESEARCH

STATUS OF FUNDS APPROPRIATED IN PRIOR FISCAL YEARS

Fiscal Year	Total Amount of Grants and Contracts	Amount Disbursed Prior to 7/1/68	Amount Disbursed in FY 69	Total Disbursements as of 6/30/69	Total Disbursements as of 9/30/69
Annual Allotment Program (Section 100)					
1965	$2,984,999.73	$2,980,693.85	none	$2,980,693.85	$2,980,693.85 1/
1966	4,462,500.00	4,452,500.00	$10,000.00	4,462,500.00	4,462,500.00 2/
1967	4,462,500.00	4,460,225.77	2,274.43	4,462,500.00	4,462,500.00 2/
1968	5,100,000.00	4,869,293.53	225,706.47	5,095,000.00	5,100,000.00 2/
Matching Grant Program (Section 101)					
1965	$ 250,000.00	$ 222,465.00	$22,135.00	$ 244,600.00	$ 244,600.00
1966	1,500,000.00	1,364,049.86	104,437.04	1,468,486.90	1,477,755.90
1967	2,000,000.00	1,504,452.16	374,248.54	1,878,700.70	1,909,553.20
1968	3,000,000.00	1,178,521.85	1,075,968.93	2,254,490.78	2,486,543.93
Additional Water Research (Title II)					
1968	$1,999,995.00	$ 672,340.91	$784,412.42	$1,456,753.33	$1,497,971.86

1/ All funds available have been disbursed. $4,085.88 in Fiscal Year 1965 Annual Allotment funds have lapsed.

2/ All funds available have been disbursed.

APPENDIX G

OFFICE OF WATER RESOURCES RESEARCH

DISPOSITION OF MONEYS DURING CALENDAR YEAR 1969

Note: "Disposition of moneys during calendar year 1969" for purposes of this appendix, means firm fund obligations made by OWRR in the form of State research program annual allotment agreements, matching grant agreements, Title II grants and contracts, and related OWRR program operations commitments during the twelve-month period ending December 31, 1969.

Budget Activity	Disposition During Jan. - June 1969 from FY 1969 Appropriations	Disposition During July - December 1969 from FY 1970 Appropriations	Total Disposition of Funds During the Calendar Year 1969
Annual Alltoment (Section 100)	$ -	$5,100,000	$5,100,000
Matching Grants (Section 101)	-	3,000,000	3,000,000
Title II (Section 200)	81,400	1,972,232	2,053,632
WRSIC	300,737	215,263	516,000
Administration	238,508	267,492	506,000
TOTAL	$ 620,645	$10,554,987[1/]	$11,175,632[1/]

1/ Estimated for the months of October, November and December 1969.

APPENDIX H

OFFICE OF WATER RESOURCES RESEARCH

DISPOSITION OF TITLE I MONEYS APPROPRIATED DURING CALENDAR YEAR 1969

Note: "Disposition of Moneys Appropriated During Calendar Year 1969" for purposes of this appendix means firm fund obligations made by OWRR in the form of State research program annual allotment and matching grant agreements.

State	Annual Allotment[1] (Section 100)	Matching Grant[2] (Section 101)	Total Disposition of Funds to State Institutes
Alabama	$100,000	$105,769	$205,769
Alaska	100,000	64,821	164,821
Arizona	100,000	50,000	150,000
Arkansas	100,000	40,303	140,303
California	100,000	89,255	189,255
Colorado	100,000	174,760	274,760
Connecticut	100,000	-	100,000
Delaware	100,000	-	100,000
Florida	100,000	72,263	172,263
Georgia	100,000	56,552	156,552
Hawaii	100,000	45,279	145,279
Idaho	100,000	64,200	164,200
Illinois	100,000	179,719	279,719
Indiana	100,000	125,066	225,066
Iowa	100,000	44,524	144,524
Kansas	100,000	17,682	117,682
Kentucky	100,000	60,910	160,910
Louisiana	100,000	-	100,000
Maine	100,000	53,888	153,888
Maryland	100,000	71,853	171,853
Massachusetts	100,000	106,738	206,738
Michigan	100,000	59,882	159,882
Minnesota	100,000	129,563	229,563
Mississippi	100,000	41,520	141,520
Missouri	100,000	17,478	117,478
Montana	100,000	33,040	133,040
Nebraska	100,000	40,000	140,000
Nevada	100,000	93,500	193,500
New Hampshire	100,000	-	100,000
New Jersey	100,000	44,397	144,397

(Continued on next page)

State	Annual Allotment[1/] (Section 100)	Matching Grant[2/] (Section 101	Total Disposition of Funds to State Institutes
New Mexico	$100,000	$ 80,474	$180,474
New York	100,000	48,200	148,200
North Carolina	100,000	60,124	160,124
North Dakota	100,000	-	100,000
Ohio	100,000	203,640	303,640
Oklahoma	100,000	35,476	135,476
Oregon	100,000	108,801	208,801
Pennsylvania	100,000	96,357	196,357
Puerto Rico	100,000	-	100,000
Rhode Island	100,000	21,711	121,711
South Carolina	100,000	63,921	163,921
South Dakota	100,000	36,020	136,020
Tennessee	100,000	15,425	115,425
Texas	100,000	66,330	166,330
Utah	100,000	89,213	189,213
Vermont	100,000	-	100,000
Virginia	100,000	66,287	166,287
Washington	100,000	6,775	106,775
West Virginia	100,000	-	100,000
Wisconsin	100,000	94,464	194,464
Wyoming	100,000	23,820	123,820
TOTAL	$5,100,000	$3,000,000	$8,100,000

1/ Annual Allotments to State institutes in calendar year 1969 were made from Fiscal Year 1970 appropriations.

2/ Matching Grants to State institutes in calendar year 1969 were made from Fiscal Year 1970 appropriations.

APPENDIX I

OFFICE OF WATER RESOURCES RESEARCH (OWRR)

WATER RESOURCES SCIENTIFIC INFORMATION CENTER (WRSIC)

Calendar Year 1969 - Expenses by Object Classification[1]

Personnel Compensation and Benefits	$119,000
Travel and Transportation	7,000
Rent, Communications, and Utilities	2,000
Printing and Reproduction	21,000
Other Services, Including Contracts[2]	270,000
Supplies and Materials	2,000
Equipment	5,000
Grants[2]	80,000
TOTAL[1]	$506,000

Note: Expenses of OWRR's Water Resources Scientific Information Center include costs of systems development, water resources research catalog preparation, augmenting the information base of water resources abstracts relating to significant water resources published and unpublished documents, making document announcement services available to the water resources community, and related technical information center activities.

[1] Expenses reported cover the period January 1, 1969, through December 31, 1969. (Expenses for the months of October, November, and December are estimated.) Because this is a calendar year statement and includes parts of funds appropriated for fiscal years 1969 and 1970, estimated expenses differ from either of the individual year appropriations for the WRSIC activity.

[2] Includes contracts (or grants) to organizations providing information base input, information base processing and output, and system study services to WRSIC.

APPENDIX J

OFFICE OF WATER RESOURCES RESEARCH (OWRR) PROGRAM ADMINISTRATION

Calendar Year 1969 - Expenses by Object Classification[1]

Personnel Compensation and Benefits	$528,000
Travel and Transportation	14,000
Rent, Communications, and Utilities	20,000
Printing and Reproduction	14,000
Other Services, Including Contracts[2]	23,000
Supplies and Materials	7,000
Equipment	7,000
Grants [2]	10,000
TOTAL [1]	$623,000

Note: Expenses of the Office of Water Resources Research include costs of developing the program and establishing program priorities; reviewing, analyzing, and selecting research project proposals for support; coordinating research activities; preparing state-of-the-art studies; advising research centers relative to research needs; monitoring progress and accomplishments under approved research grants and contracts; as well as for administrative and housekeeping functions.

[1] Expenses reported cover the period January 1, 1969, through December 31, 1969. (Expenses for the months of October, November, and December are estimated.) Because this is a calendar year statement and includes parts of funds appropriated for fiscal years 1969 and 1970, estimated expenses differ from either of the individual year appropriations for program administration.

[2] Includes contracts, grants, or fund advances to obtain advisory assistance to program management; for preparation of critical reviews by expert consultants; and for support of organizations providing housekeeping and related services to OWRR.

APPENDIX K
TITLE I PROJECTS BY STATES
1965 - 1970

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
ALABAMA								
A-001	5F	x	x	x	x			Evaluation of earthy materials for use in decontamination of water - Dixon
A-002	5B	x	x	x	x			Biological and chemical oxidation of selected organic pesticides - Leigh
A-003	2E		x					Reconsideration of flow of liquids in open channels - Shih
A-004	5A	x	x	x	x			Water resources nematology - Cairns
A-005	4A	x	x	x	x	x	x	Correlation of soil surface characteristics and rainfall-runoff-antecedent moisture relationships on small agricultural watersheds on coastal plains soils - Hendrick
A-006	5A		x	x	x	x		Studies on the interactions of bacteria and aquatic nematodes - Wilt
A-007	1B		x	x	x			Study of the effect of surfactants upon the diffusion of oxygen and hydrogen sulfide in aqueous systems - Dinius
A-008	5D			x	x			Waste water management practices in the textile industry - Hirth
A-009	2F				x			Evaluation of new techniques in electrical resistivity surveying in the Piedmont Area, Alabama - Warman
A-010	6G				x	x	x	Ecological impacts of wading birds on aquatic environment - Dusi
A-011	5D					x	x	Color removal from textile dye wastes by coagulation - Leigh
A-012	5D				x	x	x	Gamma radiation of textile waste water to reduce pollution - Judkins
A-013	1B					x		Diffusivity of oxygen and sulfide species in aqueous solutions - Dinius
A-014	4B					x	x	Evaluation of techniques for selecting sites for induced infiltration - Warman
A-015	6B						x	Identification and interrelationships of secondary benefits in waterways development - Rainer
A-016	5A					x	x	Studies on the interactions of bacteria and nematodes - Wilt
A-017	5C						x	Effect of pollutants on aquatic microorganisms - Neely
A-018	1B						x	Diffusivity of bisulfide ion in aqueous solutions - Dinius

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1/ The prefix "A" identifies a project supported by Sec. 100 (Annual Allotment) funds.
The prefix "B" identifies a project supported by Sec. 101 (Matching Grant) funds.

2/ Indicates water resources research categories as developed and defined by the Federal Council for Science and Technology (FCST), Committee on Water Resources Research. These categories and subcategories are set forth in a separate appendix to this report.

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE AND PRINCIPAL INVESTIGATOR
ALABAMA (continued)								
B-001	1B		x	x				Study of the effects of surfactants on the aqueous solubility of oxygen and hydrogen sulfide - Dinius
B-003	7B		x					Geophysical prospecting for ground water in the Piedmont Area, Alabama - Warman
B-004	5B		x					Effects of temperature and density gradients upon the movement of contaminants in saturated aquifers - Henry
B-005	5G	x	x	x				Dynamics of chemical and physical characteristics of water, bottom muds, and aquatic life in a large impoundment on a river - Lawrence
B-007	7B			x	x			Development of geochemical and geophysical techniques as an aid to determining avilability of ground water in limestone terranes - LaMoreaux
B-010	5G				x	x	x	Dynamics of chemical and physical characteristics of water bottom muds and aquatic life in a large impoundment on a river, Phase II - Lawrence
B-012	6E				x	x	x	Some legal aspects of water resource use with respect to economic development in Alabama - Street
B-015	5B				x	x	x	Biological properties of sewage lagoons at Tuskegee, Alabama - Chahal
B-017	5B					x	x	Water pollution by dairy farm wastes as related to method of waste disposal - McCaskey
B-018	2F					x		Evaluation by test drilling of geophysical prospecting for ground water in the Piedmont Area, Alabama - Warman
B-019	5E					x	x	Conservation of fresh-water resources by deep-well disposal of liquid wastes - Grubbs
B-020	2F					x	x	Aquifer performance tests under two phase flow conditions - Henry
B-025	2F						x	Methods of quantitative evaluation of ground water in limestone terranes - LaMoreaux
B-028	5B						x	Fate of trace-metals (impurities) in subsoils as related to the quality of ground water - Nelson
ALASKA								
A-001	2B	x						Atmospheric processes involved in precipitation - Ohtake
A-002	5A	x	x	x	x			Dissolved organics in interior Alaska ground waters - Birkholz
A-003	6B	x						Factors affecting the development of the water recreation potential in Alaska - Kearns
A-004	5A	x	x					Inherent and maximum microbiological activity in Smith Lake - Burton
A-005	8A		x					Analysis of salmon capibilities in steep fish ladders - Behlke
A-006	6B		x					Evaluation of water resource research needs in Alaska - Behlke
A-007	5C		x	x	x			Kinetics of vitamin-limited microbiological activity - Button
A-008	4B		x	x				Interstitial water of glacial-marine sediment - Hoskin
A-009	6F		x					Study of methods of elimination of ice jamming on northern streams - Cook
A-010	5C		x	x	x			The effects of water quality and quantity of the fauna of a non-glacial Alaskan river - Morrow

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
ALASKA (continued)								
A-011	6G		x	x				The distribution and succession of aquatic vascular plant communities in relation to physical-chemical characteristics of various lakes and ponds on the Tanana Valley, central Alaska - Harms
A-012	2C		x	x	x			A study of the freezing cycle in an Alaskan stream - Benson
A-014	5C			x	x	x		Biological degradation of wastes under psychrophilic environment - Murphy
A-015	5F			x				Foam fractionation treatment of low quality waters - Murphy
A-018	8A		x					Heat losses in a circulation water distribution system in sub-arctic Alaska - Murphy
A-019	5B			x	x			Source and mobility of iron in Alaskan waters - Hoskin
A-020	5A			x	x			Occurrence of schistomatium douthetti in surface waters of Alaska - Swartz
A-021	2C				x	x	x	Glacial melt water prediction - Long
A-022	7C				x			A ground quality summary for Alaska - Behlke
A-023	1A				x	x	x	Kinetics of microbiological modification of organic substances occurring in natural waters - Button
A-024	5F				x			Practical application of foam fractionation treatment of low quality water - Murphy
A-025	5D						x	The effectiveness of contract filter for the removal of iron from ground water - Kim
A-026	2J					x		Distribution of dissolved ions in Alaskan waters - Hoskin
A-027	6G				x	x		Effects of extreme floods and placer mining on the basic productivity of subarctic streams - Morrow
A-028	2L					x		Water quality computer model of Cook Inlet, Phase one - The hydraulic model - Carlson
A-029	6C					x		Economic considerations in resource utilization conflicts with particular regard to the Cook Inlet Basin - Tussing
A-030	5C						x	The effects of suspended silts and clays on self-purification in natural waters - Miller
A-031	2A						x	Preliminary water resources study of arctic Alaska - Carlson
B-001	3A	x						Saline conversion and ice structures from artifically grown sea ice - Peyton
B-003	6D	x						Analysis of the demands for water from the private sector in a sub-arctic area - Haring
B-006	4B		x	x				Control of ground water temperature by seasonal selectivity of recharge - Behlke
B-009	6D				x	x		Survey of water quality requirements in Alaskan campgrounds with projection of recreation demands and benefit/cost analysis for site selection - Murphy, Haring
B-014	5C						x	Influence of decomposing salmon on water chemistry - Goering
B-015	5C						x	Domestic waste discharge into a silt laden estuary - Murphy, Carlson
ARIZONA								
A-001	3B	x	x	x				Development and evaluation of water harvesting systems - Fogel, Cluff

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
ARIZONA (continued)								
A-002	4B	x						Artificial ground water recharge of paved catchment runoff water - Wilson
A-003	8B	x						Selection and testing of materials for surfacing watershed areas - Fogel
A-004	5F	x						Development of methods for making potable water from paved catchment runoff waters - Fogel
A-005	2G		x	x				Prediction of water movement in soils of arid and semi-arid regions - Evans
A-006	3C		x	x				Physiological changes in plants produced by saline solutions - O'Leary
A-007	5B		x	x				Limnology of impounded intermittent surface runoff - McConnell
A-008	2F		x	x	x	x		Geophysical investigations in alluvial basins in southern Arizona - Sumner
A-009	6B			x	x			Economic analysis of multi-product use of water on the originating watersheds in central Arizona - Martin
A-010	6A				x	x		Operations research study of water resources development and management in the Tucson area - Kisiel
A-011	3C				x	x		Optimizing salvageable water resources in a semi-arid inland basin - McConnell, Clyma
A-012	2I				x			Soil-water-plant system analysis - Hodges, Evans, Qashu
A-013	6B				x	x		Demand for municipal water in central Arizona - Farris
A-014	2A					x	x	Hydrologic characterization of forested watersheds in Arizona - Thames, Thorud
A-015	5A					x	x	Plaquing and fluorescent antibody methods for detection and identification of enteroviruses - Ludovici
A-016	2I				x			Physiological response of plants to salinity and humidity - Riley, O'Leary
A-017	2F						x	Measurement and analysis of unsaturated flow and groundwater surface profiles related to recharge and withdrawals - Evans
A-018	3B						x	The Effect of antitranspirant chemicals on the transpiration and physiology of Tamarisk - Thorud
A-019	5D						x	Removal of phosphate and secondary B.O.D. from tertiary treated wastewater by aquatic animals - Ziebell
A-020	6A						x	Modeling of hydrologic processes and water salvage procedures in semiarid regions - Fogel
A-021	6E						x	Water resources in a governmental context - Thompson
B-001	5A		x					Trace and tracer elements in ground water - Dutt, Maier
B-002	5A			x				Trace and tracer elements in ground water - Phase II - Dutt
B-003	6E			x	x	x	x	Economic implications of water policy in Arizona - Kelso
B-004	5A				x			Trace and tracer elements in ground water, Phase III - Dutt
B-005	3B				x	x	x	Development of economic water harvest systems for increasing water supply - Cluff
B-007	7A					x	x	Efficiency of data collection systems in hydrology and water resources for prediction and control - Kisiel
B-012	4C						x	Hydrological and environmental controls on water management in semi-arid urban areas - Resnick

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970						PROJECT TITLE and PRINCIPAL INVESTIGATOR
		5	6	7	8	9	0	
ARKANSAS								
A-001	6G	x	x	x	x			Environmental changes produced by cold-water outlets from three Arkansas reservoirs-Hoffman, Strawn, Kilambi
A-002	3F	x	x	x	x	x		Development of automated sub-irrigation system - Bryan
A-003	7C	x	x	x				Quantitative analysis of stream-flow-rate extremes - Heiple
A-004	5B		x	x	x			Interaction of inorganic and organic fertilizer materials with pesticides as related to water quality in soils - Brown
A-005	5B		x	x	x			Virus movement in groundwater systems - Drewry
A-006	6A	x	x	x				Water resources research needs in Arkansas - Sparks
A-007	6G				x	x	x	Effects of water diversion of biota and water quality in the State of Arkansas - Kilambi, Hoffman
A-008	7B				x	x	x	Digital systems for on-site data collection for water quality analysis - Testerman
A-009	6G				x	x	x	Impoundment effects on the helminth and copepod parasites of reservoir basses - Becker
A-010	4B					x	x	Groundwater-surface water integration study in the Grand Prairie region of Arkansas - Hoskyn
A-011	6G					x	x	A study of phytoplankton dynamics in Lake Fayetteville as a means of assessing water quality - Meyer
B-001	6D			x	x	x	x	Water resources planning studies, Arkansas and Oklahoma - Heiple
B-002	2K				x	x		Distribution of trace elements in impoundments - Nix
B-004	4B				x	x	x	Sedimentation and in-place filtration during flow through earth fractures - Babcock
B-012	5B					x	x	A eutrophication model of the White River Basin above Beaver Reservoir in northwest Arkansas - Gearheart
B-014	2K						x	Distribution of trace metals in a warm water release - Nix
CALIFORNIA								
A-001	5A	x						Vacuum cup emission spectrography as a routine method for quantitative water quality determinations for trace elements - Bush
A-002	6G	x	x					The impact of water export on the area of origin: A case study in the Owens and Mono Basins - Parsons
A-003	6B	x	x	x				Systems analysis for ground water basin management - Todd
A-004	5G	x	x	x				The management of surface water hydrologic systems for water quality control - McGauhey

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
CALIFORNIA (continued)								
A-005	3C	x	x	x	x			The acceptability of mineral taste in domestic water - Knutson
A-013	5C	x	x					The persistence of residues and the fate of herbicides in rice fields and rice field effluents - Seaman
A-014	6E		x	x				Municipality as a water policy determining entity - Crouch
A-015	2F		x					Problems in water transport through porous media - Perrine
A-016	2B		x					Relationship between the anomalies of the Pacific Ocean temperatures and those of California rainfall - Bjerknes
A-017	5A		x					Reducing the pollutional burden of food plant wastewaters - Hart
A-018	6A	x						Policy developments in the Pacific Southwest water plan in relation to the strategy of western regional water development - Engelbert
A-019	6A	x						Application of optimization techniques to problems in water resources development - Hall
A-020	3F	x						Hydraulics of water advance over a solid surface - Strelkoff
A-021	2B				x	x	x	Pacific Ocean influence upon California rainfall - Bjerknes
A-022	6E				x			Local water district as an urban water policy determining entity - Crouch
A-023	2J				x			Cross sectional shapes in bends of degrading rivers - Einstein
A-024	5G				x			Predicting the effects of changes in irrigation water temperature caused by water projects - Hagan
A-025	6C				x	x		Comparative study of the use tax as a means of allocation of water resources in a conjunctive use system - Weschler
A-026	3F				x			Soil temperature as a criterion for allocating water supply for crop use - Wallace
A-027	5A			x				Development of analytical methods for pesticide contaminants in domestic, irrigation and pond waters - Gunther
A-028	2D			x				Evaporation from finite areas with constant sources - Dracup
A-029	4A				x	x	x	Physical, chemical and microbiological factors affecting the discharge of water into drain tile - Richards
A-030	6F					x	x	Public attitudes toward reuse of reclaimed water - Knutson
A-031	4A					x	x	Drainage design as influenced by conditions in the vicinity of the drain line - Luthin
A-032	2F				x	x	x	Hybrid computer simulation of ground-water basins - Karplus, Dracup
A-033	6A					x	x	System identification and multi-level optimization of integrated ground water systems - Dracup
B-001	6A		x	x	x			Optimization of water resources development - Hall, Shephard

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970						PROJECT TITLE and PRINCIPAL INVESTIGATOR
		5	6	7	8	9	0	
CALIFORNIA (continued)								
B-002	7B		x	x	x			Induced electrical polarization and ground water - Ward
B-005	2A			x	x	x		Generalized analysis of small watershed responses - Amorocho
B-006	4B			x	x	x	x	Optimization of wells and recharge facilities in conjunctive use of ground-water reservoirs - Scott
B-008	6B		x	x	x			On-farm irrigation water supplies and costs in relation to cropping systems and production adjustments in the Sacramento Valley - Hedges
B-009	6B		x	x	x	x	x	The development of water resources in California in relationship to plans and programs for western region water development - Engelbert
B-012	2E		x	x				The mechanics of open channel flow systems - Strelkoff, Amorocho
B-013	6B	x	x	x				A case study of demographic and electoral correlates of Los Angeles County water bond support, 1960 - Marvick
B-017	6A		x	x	x	x	x	A dynamic input-output and mathematical programming analysis of western regional water resources - McGaughey
B-028	4B			x	x			Dynamic integrated management of a depleted ground water reservoir and a surface water supply system - Dracup
B-029	3F			x	x	x	x	Changes in enzymes in the plant as related to water supply and usage - Hsiao, Huffaker
B-037	2E				x	x	x	Mechanics of flow in open channel systems - Strelkoff, Amorocho
B-041	4B				x	x	x	Systems analysis for ground water management - Todd
B-054	3F				x	x	x	Potential usefulness of antitranspirants for increasing water use efficiency of plants - Hagan
B-061	6A				x	x	x	Optimization of water resources development, Phase II - Hall
B-065	6E				x	x		Allocative impacts of Federal and State water development law - Shapiro
B-066	4B				x	x	x	Evaluation of ground water resources Livermore Valley, California - Witherspoon
B-067	2F					x	x	Inductive electromagnetic methods for mapping and evaluating aquifers - Ward
B-068	6B					x	x	On-farm irrigation water supplies and costs in relation to cropping systems and production adjustments in the Sacramento Valley - Hedges
B-072	2G					x	x	Characterization of soil nonwettability and the development of criteria for the most economic treatment of these soils - Letey
B-090	6G						x	Ecological and physiological implications of greenbelt irrigation - Goodin, McKell
B-091	6A						x	A stochastic multi-level optimization technique for design of a multi-purpose water resource project - Mobasheri, Klinger

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	 6	 7	 8	 9	 0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
CALIFORNIA (continued)								
B-094	6B						x	Effects of cost, technology, supply and quality of irrigation water on cropping patterns, income, and output of farm firms in the Imperial Valley, California, Stage I - Snyder, Moore
B-100	4C						x	The energy and moisture budget of the urban interface as affected by cyclonic storms - Terjung
B-107	6A						x	Optimization of water resources systems incorporating earthquake risk - Duke, Dracup
COLORADO								
A-001	5G	x	x	x	x	x		Changes in the physical and biological characteristics of ground water reservoirs and adjacent surface waters - Morrison
A-002	4A	x	x	x	x	x		Surface water management - Simons, Garstka
A-003	6B	x	x	x				Water storage management - Ward, Yevdjevich
A-004	4A	x	x	x	x	x		Atmospheric water - Grant, Riehl, Rasmussen
A-005	6B	x	x	x	x	x		The economics and administration of water resources - Barkley
A-006	5C				x	x	x	Water temperature as a quality factor in the use of streams and reservoirs - Ward, Hagen, Ryder
A-007	5D						x	The mechanisms of waste water treatment at low temperature - Morrison
A-008	5D						x	Combined cooling and bio-treatment of beet-sugar factory condenser water effluent - Lof
A-009	2A						x	Multivariate analysis of small watershed rainfall - runoff relations - Holland
A-010	5G						x	Water quality management decisions in Colorado - Skogerboe
A-011	6A						x	Selection of test variable for minimal detection of basin response to natural or induced changes - Morel-Seytoux
A-012	7B						x	Identification of urban watershed units using remote multispectral sensing - Miller
A-013	6E						x	Economic, political and legal aspects of Colorado water law - Nobe
B-001	3F		x	x	x			Hydraulic operating characteristics of low gradient border checks in the management of irrigation water - Evans, Heermann
B-005	2A			x	x			Flood from small watersheds - Smith, Reich, Yevdjevich
B-006	6E		x	x	x			An exploration of components affecting and limiting policy making options in local water agencies - Hill

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
COLORADO (continued)								
B-007	6B	x	x	x	x	x	x	Economics of ground water development in the high plains of Colorado - Barkley
B-008	3F	x	x	x	x	x	x	Evaporation from soil as affected by salt, structure and texture - Kemper, Lahav
B-013	4B				x	x	x	Ground water recharge as affected by surface vegetation and management - Kemper, Doxtader, Danielson
B-014	4A				x	x	x	Sedimentation and contaminant criteria for water resources planning and management - Shen
B-015	3F				x	x	x	Evaporation of water as related to wind barriers - Cermak, Plate
B-022	2F					x	x	Geohydraulics at the unconformity between bedrock and alluvial aquifers - Waltz
B-023	5B					x	x	A system of geologic evaluation of pollution potential at mountain dwelling sites - Waltz, Morrison
B-024	3F					x	x	Hydraulic operating characteristics of low gradient border systems, Phase II - Evans, Heermann
B-029	6E					x		An exploration of components affecting and limiting policy making options in local water agencies, Phase II - Hill, Garrison
B-030	2A					x	x	Experimental investigation of small watershed floods, Phase II - Yevdjevich
B-033	2G					x	x	A systematic treatment of the problem of infiltration - Morel-Seytoux
B-035	2A					x	x	Atmospheric water balance and the forecast of annual runoff from the upper Colorado River Basin - Rasmussen
B-039	3F						x	Improvements in moving sprinkler irrigation systems for conservation of water - Miles, Evans
B-042	6B						x	Economic and institutional analysis of water quality standards and management - Nobe, Radosevich
B-043	6E						x	Consolidation of irrigation systems - Phase I - Engineering, legal, and sociological constraints and facilitators - Skogerboe, Radosevich, Valachos, Ellenbogen
B-051	6E						x	Local water agencies, communication patterns and the planning process - Hill
CONNECTICUT								
A-001	5D	x	x	x	x	x	x	Individual waste disposal systems - Wheeler
A-002	2D	x	x					Diffusion through multiperforate septa - Lee
A-003	5C	x	x	x	x	x		Effects of simultaneous variation of temperature and dissolved oxygen on the resistance of fishes to controlled pollutants - Whitworth

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970						PROJECT TITLE and PRINCIPAL INVESTIGATOR
		5	6	7	8	9	0	
CONNECTICUT (continued)								
A-004	4B	x	x	x		x		Relation of bedrock fracture systems to underground water supplies in the Stafford Springs, South Coventry, Spring Hill and Westford quadrangles - Aitken
A-005	5G	x	x	x	x	x		Rate and direction of ground water circulation in close synchronous pumping time and rates - Frankel, Thomas
A-006	6B	x	x					The role of regional planning in the public management of water resources: The case of the Farmington River Basin - Kasperson
A-007	5B	x	x	x				Correlation of trace elements in ground waters and aquifers within the Connecticut River Basin - Liese
A-008	2B	x	x	x				Analysis of quasi-periodic weather data - Posey
A-009	8B	x	x	x	x	x		Reverse filter erosion protection - Posey
A-010	1B	x	x	x	x	x		The determination of the engineering thermo-physical properties of solutions containing dissolved solids - Fisher
A-011	5G	x	x	x	x	x		Reduction of river heat pollution by turbulence stimulation - Scottron
A-012	6E			x	x	x		Integration of Connecticut water rights laws and pollution control laws - Leonard
A-013	1B			x	x	x	x	Ion-ion and ion-molecule interactions in aqueous salt solutions - Masterton
A-015	5C			x	x	x	x	Variability in diatom morphology and water pollution - Trainor
A-016	5G			x	x	x	x	Water quality control with synthetic polymetric flocculants - Dixon, Zielyk
A-017	5C				x	x		Studies on phosphorus transformations in eutrophic lakes - Tilton
A-018	2G			x	x	x	x	Oxygen status of soil air and soil water as influenced by oxygen transfer through soil profile - Wengel
A-019	5D					x	x	Air oxidation of organic compounds in aqueous systems - Sundstrom
A-020	2E					x	x	Measurement and analysis of natural type surfaces affecting fluid flow - Posey
A-021	2H				x	x	x	Experimental studies of air and water interfacial interaction - Lin
A-022	5A					x	x	Development of instrumental techniques for the analysis of trace organic constituents in water - Collins
A-023	1A					x	x	Scattering measurements on alkali - H_2O systems - Moran, Pollack
A-024	2K						x	Structural aspects of amide-water systems - Lindstrom
A-025	5B						x	Relative pollution strengths of undiluted waste materials discharged in households and the dilution water used for each - Laak
A-026	5A					x	x	The evaluation of similarities of algal communities of artificial and natural substrates - Hansmann
A-027	2I						x	Changes in resistance to flow of water through a soil-plant system - Janes

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
CONNECTICUT (continued)								
A-028	6E						x	A study of legal and administrative practices relating to lake pollution in the northeast - Kennard
DELAWARE								
A-001	5D	x	x	x				Increased gas transfer in biological reactors of interest to waste water reclamation - Shane
A-002	3F	x	x	x	x			Increasing water use efficiency by altering plant growth, the plant micro-climate and the method of irrigation - Fieldhouse
A-003	6E	x	x	x	x			Investigation of the economic and governmental aspects of water resources development in Delaware - Tennian, Overman
A-004	4B	x	x	x	x	x		The ground water flow system in the Delmarva Peninsula - Mather, Varrin
A-005	5F	x	x	x	x			Mass transfer rates in structured media, with emphasis on systems of interest in water conservation and re-use - Metzner
A-006	6G			x	x	x	x	Flushing pattern of certain tidal streams in Delaware - Daiber
A-007	5C				x	x		Effect of boron in biological waste treatment - Banerji
A-008	5D				x	x	x	Mass transfer and chemical reaction in two phase flow - Russell
A-009	1B					x	x	Rotational stability in dilute polymer solutions - Denn
A-010	3F					x	x	Plant-water-use effeciency with growth regulators and transpiration suppressants - Fieldhouse
A-011	5D						x	Anaerobic treatment of starch wastewaters - Rasmussen
A-012	3F						x	Water use efficiency of vegetable crops grown over asphalt moisture barriers - Scarborough
A-013	6B						x	Water resources management in Delaware - Tannian
B-001	6D		x	x	x			Economic and engineering aspects of water in Delaware agri-business industry - Smith
B-002	2F				x	x	x	Morphology and hydrology of pleistocene deposits, Delaware - Groot
B-003	3E					x	x	Economic and engineering aspects of water in Delaware's agri-business industry - Phase II - Smith

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
FLORIDA								
A-001	6E	x	x	x				A comprehensive study of Florida water law - Maloney
A-002	5C	x	x	x	x			Factors affecting accelerated eutrophication of Florida lakes - Putnam, Furman
A-003	3F	x	x	x	x			Irrigation efficiency - Myers
A-004	4B	x	x	x				Rate of solution of limestone in the Karst Terrane of Florida - Brooks
A-005	4B		x	x	x			Radiometric and structural investigation of the Floridian aquifer in northern and central Florida - Osmond
A-006	2L			x				Net effect of wind on recreational tidal streams in Florida - Moreau
A-007	2L				x	x	x	Residence times of waters behind barrier islands - Dean, Vastano
A-008	3F				x	x	x	Influence of inadequate water supply on metabolism in biological systems with emphasis on protein synthesis and nucleic acid metabolism - West, Brook
A-009	6E				x	x		Model water use act for the State of Florida with comments - Maloney
A-010	6D				x			Prediction model for water use by population structure - Bock, Cross, Kubat, Vandiver
A-011	2F					x	x	Uranium and hydrogen radionuclides as natural tracers in the Floridan aquifer - Osmond, Buie
A-012	5A					x	x	The activation-chromatographic elemental and structural analysis of fresh water sources - Cram
A-013	5B					x	x	Movement and adsorption of pesticides in sterilized soil columms - Mansell
A-014	2A						x	Prediction of solar and atmospheric radiation for energy budget studies of lakes and streams - Huber
B-004	2H						x	Trophic state of lakes in north central Florida - Brezonik
B-005	6B						x	An optimum water allocation model based on an analysis for the Kissimmee River Basin - Reynolds
GEORGIA								
A-001	5G	x	x	x				The monitoring of integrated light levels and average temperatures in lakes - Birkebak
A-002	2K	x	x	x	x	x		Adsorption of ions in trace concentration on soil and silt particles - Eichholz
A-003	5C	x	x	x	x			A method for predicting the effect of pollutants on the dynamic oxygen balance of water - Gates
A-004	4A	x	x	x	x	x		Tracing storm and base flow to variable source areas on a forested watershed - Hewlett

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
GEORGIA (continued)								
A-005	5G	x	x	x	x			Biological, chemical and physical factors controlling the concentration of manganese in the hypolimnion of impoundments - Ingols
A-006	4B	x	x	x	x	x	x	The artesian system in Georgia: Stratigraphy and hydrology of the Ocala - Stanley, Rich
A-007	4B	x	x					Determination of the content and behavior of specific trace cations in ground and surface waters, and their adjustment to passage in or on subsurface geological formations of contrasting chemical and mineralogic compositions - Salotti
A-008	2K	x	x	x	x			Extraction of potassium from fresh and saline waters by clay minerals - Weaver
A-009	7A		x	x				Efficient design and utilization of rainfall networks - Snyder
A-010	3E		x					Survey of the nature and magnitude of the water research needs of the textile industry of Georgia - Hyden
A-011	5G			x	x			Phosphorus budgets of Lakes Sidney Lanier and Hartwell, Georgia - Scott
A-012	6A				x			Prediction models for water quality parameters: Phase I - Hines
A-013	7C				x	x		Method of determining and mapping the hydrologic response of ungaged watersheds in the southeast - Woodruff
A-014	6D				x			Water requirements of North Georgia manufacturing industries - McGregor
A-016	8A					x		Unsteady flow of dilute aqueous high polymer solutions in pipes - Mayer
A-017	1B					x	x	The structure and properties of water solutions - Pierotti
A-018	2A					x	x	A geographic analysis of the hydrologic response in the southeastern United States - Woodruff
A-019	6E					x	x	Attitudes and attitude change relating to water resources - York
A-020	1B				x	x	x	Application of modern electroanalytical techniques to the analysis of heavy metals in water - Sturrock
A-021	1B				x	x	x	A laboratory study of the soluble metals in rocks, saprolite, and soil from the Broad Quadrangle, Georgia - Salotti
A-022	2A					x	x	A study of subsurface flow into mountain streams as related to topography and partial source areas - Hewlett
A-023	6A					x	x	Prediction models for water quality parameters: Phase II - Hines
A-024	6E						x	The effect of municipal water service policies on economic growth in surburban areas - Whitlatch
A-025	2A						x	Soil drainage and the depletion phase of the upland hydrograph - Nutter
A-026	2K						x	Chemical characterization of dissolved organic matter and its influence on the chemistry of river water - Reuter

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
GEORGIA (continued)								
B-002	5G		x	x				A study of the water quality gradients in Lake Sidney Lanier, Georgia - Hewlett, Holder, Barnhart
B-003	4B		x	x				Fresh-water canal as a barrier to salt-water intrusion - Carstens
B-004	2J		x					The effects of permeable bed on sediment motion - Martin
B-007	6G			x	x			A study of the energy flow through selected components of a small aquatic ecosystem - Scott
B-008	5D		x	x				Radiotracer studies on rapid sand filtration - Eichholz
B-009	6B		x	x	x			Interrelations between river basin development and metropolitan areas - Kelnhofer
B-010	2G				x	x		Studies of saprolite and its relation to the migration and occurrence of groundwater in crystalline rocks - Hurst
B-011	6D		x	x	x	x		The demand and price structures for water in a humid area - North
B-012	5G			x	x			Determination, evaluation and abatement of color in textile plant effluents - Flege
B-013	6E			x	x			Water law of Georgia - Collins
B-019	2J				x	x	x	Effect of a permeable bed on sediment motion, Phases II and III - Martin
B-020	5D				x	x	x	Radiotracer studies on rapid sand filtration, Phase II - Eichholz
B-022	8A				x	x	x	Two-phase flow in a vertical bend - Carstens
B-023	5G				x	x	x	Investigation of the influence of valence states of iron and manganese upon the biota of the hypolimnion - Heise
B-024	6E				x	x		Measurement of community opinion relating to public water supplies - York
B-027	5B					x	x	Determination of degraded dyes and auxiliary chemicals in effluents from textile dyeing processes - Flege
B-030	6E					x		Water law of southeastern estuaries - Kates
B-033	2K					x	x	The effect of clay minerals on the chemical composition of fresh and saline waters - Weaver
B-035	2L					x	x	Estuarine hydrography and its role in transport on naturally produced foods and pollutants - Linton
B-038	6E						x	A program for metropolitan water management -
B-045	6E						x	A citizen panel for Atlanta area studies: Field experimentation and methodological substudies - York
HAWAII								
A-001	5B	x	x	x	x	x		Pollution effects on ground water recharge in Hawaii - Lau

HAWAII (continued)

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970						PROJECT TITLE and PRINCIPAL INVESTIGATOR
		5	6	7	8	9	0	
A-007	4B	x						Development and hydrology of ground water basins, with special reference to sea water encroachment in the Honolulu region - Lau, Cox
A-008	3F	x						Effect of nulches on evapotranspiration from Latosol - Ekern
A-009	7B		x					Feasibility of seismic exploration for ground water - Cox
A-010	7B		x	x				Pilot Evapotranspiration study - Ekern
A-011	2A		x					Hydrologic conversion of the Ewa Beach testwell - Cox
A-012	6B			x	x	x		Methods for determining the economic productivity of irrigation water for the production of sugar in Hawaii - Davidson
A-013	5F			x				Characterization and removal of refractory color colloids from Hawaiian surface waters - Burbank
A-014	3F				x	x	x	Evapotranspiration by sugar cane - Ekern
A-015	2F				x	x		Tidal effects on ground water hydraulics in Hawaii - Williams
A-016	2A				x	x		Water tracing and dating in Hawaii hydrologic cycle - Lau
A-017	2I						x	Water budget of sprinkler irrigated sugarcane - Ekern
A-018	5B						x	Pollution and reuse of wastewater effluents and stormwater in Hawaii - Lau
A-019	6E						x	Water resources institutions in Hawaii: A preliminary study - Yamauchi
A-020	2F						x	Analog simulation of tidal effects on ground water aquifers - Williams
A-021	2A						x	Water tracing and dating in Hawaii hydrologic cycle, Phase II - Lau
A-022	2F						x	Revision of Hawaiian hydrogeology - Macdonald
A-023	4B						x	Evaluation of artificial recharge practices in Hawaii - Peterson
A-024	7C						x	Inventory of published information on Hawaiian water resources - Chang
A-025	1A						x	Thermal properties of sea water - Chou
B-003	2E			x				Pilot study of small watershed flood hydrology in Hawaii, Phase I - Wu
B-005	2F			x				Geophysical exploration for Hawaiian ground water - Cox, Adams
B-006	2E				x			Pilot study of small watershed flood hydrology in Hawaii, Phase II - Wu
B-008	2F				x	x	x	Geophysical exploration for Hawaiian ground water, Phase II - Cox, Adams
B-010	2K				x			Identification of irrigation return water in the subsurface - Young
B-011	2F					x		Geophysical exploration for Hawaiian ground water, Phase III - Adams, Cox
B-012	2K					x	x	Identification of irrigation return water in the sub-surfaces, Phase II - Young
B-013	2K						x	Identification of irrigation return water in the sub-surface, Phase III - Young
B-015	2F						x	Remote sensing of water with electromagnetic radiation from 10-1 to 1015 Hertz - Adams

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
IDAHO								
A-001	2G	x						Effect of external air pressure on liquid flow through porous media - Bloomsburg
A-002	6C	x						High-lift pumping and the impact upon the development of desert land - Folz
A-003	5A	x	x					Effects of stream sedimentary deposits on the distribution and metabolic activity of the bottom fauna in Coeur d'Alene, Idaho - Ferguson
A-006	7B	x						Electronic measurement and telemetry of hydrologic data - McKean
A-008	1A	x	x					Study of solid-liquid phase precipitation measuring device - McKean
A-009	2F		x	x	x			Movement of water from canals to a ground water table - Brockway, Bloomsburg
A-010	6F	x	x	x				A critical study of the Idaho code of laws together with various agencies and their runctions in the field of water resources - Walenta
A-011	4B	x	x					Detailed ground water investigation of the Moscow Basin, Idaho - Jones
A-012	2A	x	x	x	x			A microclimatic profile from the Snake River to the Clearwater Mountains - Day
A-013	5A	x	x	x	x			Lethal index for classifying chemicals which effect water quality of aquatic life - MacPhee
A-014	6G	x	x	x	x	x		Characteristics of major forest and range watershed types in Idaho - Belt
A-015	4B	x						Soil, pesticides, and quality of water - Lewis
A-016	3B		x	x	x	x		Hydrology of frozen ground floods - Robertson
A-017	6B		x	x	x			Economic value of water in different uses within agriculture - Lindeborg
A-018	5G			x	x	x		Limnological studies of lentic waters in Idaho - Rabe
A-019	7B			x	x			Studies on methods of soil water determination - Hagen
A-020	4B			x				Detailed hydrogeology of Albion Basin, Cassia County, Idaho - Jones
A-021	2G			x	x	x		Temporal, horizontal and vertical variability of water chemistry in the unsaturated zone of fine grained soils - Williams
A-022	5C				x	x		Aquatic environment and food habits of mayflies - Brusven
A-023	3F					x	x	Investigation of seepage reduction by natural processes in irrigation canals-Brockway
A-024	5C					x	x	Biological productivity of Coeur d'Alene River as Related to water quality - Rabe
A-025	2F					x	x	Effect of physical properties of porous media on groung water movement - Bloomsburg
A-026	5C						x	Effects of siltation and coarser sediments on distribution and abundance of stream-inhabiting insects - Brusvan
A-027	8A						x	Investigation of culverts and hydraulic structures used for fishways and the enhancement of fish habitat - Watts
A-028	2A						x	Investigation of factors relative to groundwater recharge in Idaho - Williams
A-029	2A						x	Rainfall and snowmelt runoff from intermediate elevation watersheds - Molnau

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970						PROJECT TITLE and PRINCIPAL INVESTIGATOR
		5	6	7	8	9	0	
IDAHO (continued)								
B-006	6B				x	x		Relationship of pumping lift to economic use of ground water for irrigation - Corey, Lindeborg
B-009	2D					x	x	Simulation model for evaluation of interception from forest - Belt
B-014	6B						x	Development of methodology for evaluation of wild and scenic rivers in Idaho - Michalson
ILLINOIS								
A-001	5G	x	x	x				Influence of turbulence on surface reaeration - Holley
A-002	2F	x	x					Further study of aquifer performance - Rose
A-003	2G	x	x					The analysis of the uptake of water by plant root systems - Klute
A-004	2G	x	x	x				Effect of organic compounds on the ion-exchange adsorption of radioactive cations on clays - Ewing
A-005	5B	x	x					Occurrence of nitrate in water wells - Larson
A-006	2E	x	x	x				Microscopic determination of tractive force distribution in free-surface water conveyances - Wenzel
A-007	6B	x	x					Meteorological drought and its social impact in Illinois - Booth
A-008	6C	x	x	x				Economic evaluation of pricing water supply in Illinois - Bassie
A-009	3B	x	x	x				Moisture depletion rates and source of flow for the Grantsburg soils in southern Illinois - Boggess
A-010	5G	x	x	x				Basic studies of jet flow pattern related to stream and reservoir behavior - Maxwell
A-011	6B	x	x	x	x			Development of drainage assessment procedures based on physical features in Illinois - Jones
A-012	7A	x	x					Feasibility study of quantitative radar measurement of precipitation of Lake Michigan - Changnon
A-013	2F	x	x	x				Geologic controls on ground water discharge in selected small stream basins in Illinois - Farvolden
A-014	5A		x					Spectrophotometric determination of nitrate in water using 2-nitroso, 1-naphthol, 4-sulfonic acid - Caskey
A-015	5A		x	x	x			Use of endocommensal molluscan ciliated protozoans as indicators of water quality and pollution in Illinois - Small
A-016	5F		x	x				Co-oxidation of organic molecules by methane-oxidizing bacteria growing at the expense of methane - Kallio

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
ILLINOIS (continued)								
A-017	7C		x	x				Evaluation of water resources development in Illinois - Sutton
A-018	5C			x	x			Studies of the population dynamics and physiological ecology of three species of fresh-water isopods (crustacea isopoda) - Kendeigh
A-019	5G			x	x	x		Transport processes of particles in dilute suspensions in turbulent water flow - Jones
A-020	5F			x	x			Virus removal by chemical flocculation - Engelbrecht
A-021	5G				x			Influence of turbulence on surface reaeration (Phase II) - Holley
A-022	5A				x	x	x	Reagents for determinations of trace impurities in water - Caskey
A-023	2D				x	x	x	Water transport in the system, soil-plant-atmosphere - Klute
A-024	5B				x			Free-living ciliate protozoa from the biologically polluted Salt Fork Stream in Illinois - Small
A-025	6B				x	x		Analysis of literature on the recreational aspects of water resources research - Storey
A-026	8A				x	x	x	Microscopic investigation of tractive force distribution in open channels - Wenzel
A-027	6B				x			Impact of community water systems in small towns - Wills
A-028	2D					x	x	Effect of water availability on photosynthesis of plants - Boyer
A-029	6A					x		Stochastic analysis of hydrologic systems - Chow
A-030	6F					x	x	An appraisal of flood regulations in the States of Illinois, Indiana, Iowa, Missouri and Ohio - Keith
A-031	2I					x	x	An experimental study of eddy diffusion coefficients, evapotranspiration and water use efficiency - Millington, Peters
A-032	7B					x	x	Device for field determination of heavy metals in natural waters - Van Atta
A-033	2J					x		Hydraulic resistance in alluvial channels - Yen
A-034	5C						x	Accumulation of metals in the aquatic food chain in the Illinois River - Mathis
A-035	5B						x	Fate of aquatic herbicides in the aquatic environment - Hiltibran
A-036	5D						x	Biomass production for the improvement of the quality of food processing plant effluents - Ordal
A-037	5G						x	Effects of oxygen demand on surface reaeration rates, Phase II - Holley
A-038	5B						x	Microbial modifications of ground water - Wolfe
A-039	5G						x	Growth regulators and mineral nutrition in aquatic plant control - Presley
A-040	5C					x	x	Assimilation of a waste treatment plant effluent by a creek-river-mainstream impoundment system - Larimore

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970						PROJECT TITLE and PRINCIPAL INVESTIGATOR
		5	6	7	8	9	0	
ILLINOIS (continued)								
B-001	5C		x	x	x			Distribution of drift organisms in relation to pollution and the impoundment of the Kaskaskia River - Larimore
B-002	2G		x	x	x			Non-Darcy flow characteristics of water as influenced by clay concentration and swelling pressure - Miller
B-005	5G			x	x			Hydraulic geometry of Illinois streams - Stall
B-006	5D			x	x			Probabilistic analysis of wastewater treatment and disposal system - Ewing
B-009	6E			x	x			Intergovernmental relationships in the administration of water resources - Krausz
B-010	2F			x	x			Statistical porous media hydrodynamics - Scheidegger
B-014	6B				x	x	x	Economic analysis of water use in Illinois agriculture - Swanson
B-017	8A				x	x	x	Boundary effects on jet flow patterns related to water quality and pollution problems - Maxwell
B-018	2A				x	x	x	Effect of raindrop impact and surface roughness on sheet flow - Wenzel
B-022	5D				x	x		Catalytic oxidation of organic compounds in waste waters - Smith
B-023	2E					x	x	Hydraulic geometry of streams - Stall
B-025	2A					x	x	Relation of floodplain pools to the biological production of the Kaskaskia River and its mainstem reservoirs - Larimore
B-028	5B					x	x	Effect of chlorination of ciliate protozoa and their role as a barrier to stream pollution - Small
B-030	6A					x	x	Advanced methodologies for water resources planning - Chow
B-032	6B					x	x	The urban snow hazard - Rooney, Baumann
B-034	6D					x	x	Water quality criteria for selected recreation uses - Storey, O'Connor
B-035	2A						x	Study of the hydrology for models of the Great Lakes - Meredith, Stout, Jones
B-036	3F						x	Relationship of plant moisture status to irrigation need in corn and soybean plants - Boyer
B-038	2A						x	Stochastic analysis of hydrologic systems, Phase II - Chow, Kareliotis
B-042	5G						x	Transport processes of particles in dilute suspensions in turbulent water flow, Phase II - Jones
B-043	4A						x	Methodologies for flow prediction in urban storm drainage systems - Yen
INDIANA								
A-001	2A	x	x	x	x	x		Estimation of runoff from small watersheds in Indiana - Delleur
A-002	6A	x	x	x				Statistical analysis of groundwater use and replenishment - Johnson
A-003	2E	x	x	x	x	x		The hydraulics and geomorphology of meandering rivers with flood plains - Toebes

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970						PROJECT TITLE and PRINCIPAL INVESTIGATOR
		5	6	7	8	9	0	
INDIANA (continued)								
A-004	2G	x	x	x	x			Characterization of the rate of water infiltration into soil - Swartzendruber, Monke
A-005	5C	x	x	x	x	x	x	Effect of pesticide residues and other organo-toxicants on the quality of surface and ground water resources - Chandler, Monke, Moe
A-006	4B				x			Analysis of ground water use, replenishment and aquifer characteristics in Bartholomew County, Indiana - Rockaway
A-007	2A				x	x	x	An integrated system of stream classification - Melhorn
A-008	9A				x	x		Water resources research, manpower and training needs for Indiana - Wiersma
A-009	8A					x	x	Fluctuation of reservoir levels and the related cause of landslides - Harr
A-010	2G					x	x	Quantification and prediction of the infiltration phase of the hydrologic cycle - Swartzendruber
A-011	6A					x	x	Improved methods for estimating manpower needs for water resources development-Miller
A-012	6A						x	The application of systems analysis to water resources in the Wabash Basin: A-1 - Simulation model for water systems analysis in the Wabash Basin - Toebes
A-013	6A						x	The application of systems analysis to water resources in the Wabash Basin: A-2 - A water quality control dimension of a water resources simulation model of the Wabash Basin - Bell
A-014	6A						x	The application of systems analysis to water resources in the Wabash Basin: A-3 - The impact of institutional and political factors on management - Quinn
A-015	6C						x	Ecologic impact of human activities on water resource environments - Ferris
B-002	4C			x	x	x		Effect of urbanization on runoff in small watersheds - Delleur
B-003	2A			x	x	x	x	Mathematical simulation of hydrologic events on ungaged watersheds - Monke
B-005	2G			x	x	x	x	Electrical effects on water infiltration into soils - Swartzendruber
B-008	2A					x	x	Assembly and analysis of hydrologic and geomorphologic data for small watersheds in Indiana - Delleur
B-013	2J					x	x	Relationship between the erodibility of soils and the sedimentation rate of reservoirs - Kohnke
B-014	2G					x	x	Dynamics of water infiltration into soil as governed by surface crusting and sealing - Swartzendruber
B-016	2A						x	Simulation of the hydrology of ungaged watersheds - Higgins
B-020	6C						x	Economic analysis of optimal water quality management - Whinston
B-022	2A						x	The effect of urbanization on hydrology of watersheds - Rao, Delleur

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
IOWA								
A-001	6D		x	x	x			Economic factors in the establishment of water quality stream standards - Dougal
A-002	6B		x	x	x			Evaluation of flood damage to corn from controlled depth and frequency of flooding - Beer
A-003	2G		x	x	x			Moisture movement to vertical sinks in water - unsaturated soil - Kirkham
A-004	6F		x	x	x			Recession characteristics of Iowa streams - Howe
A-005	6D		x	x	x			Competitive recreational uses of selected Iowa lakes - Haugen
A-006	2E		x	x	x			Discharge, valley form relationships of selected Iowa streams - Salisbury
A-007	5A		x	x	x			To collect, characterize, and study the biodegradability and the chemical oxidation of carbon-adsorbed materials from effluents from sewage plants - Sletten, Johnson
A-008	5G	x						Pollen and diatoms in sediments of a post-pleistocene lake - Dodd
A-009	3C	x						Preimpoundment survey of vegetation of Saylorville Dam impoundment area - Landers
A-010	6E	x						Legal aspects of small watershed program in Iowa - Hines
A-011	5B		x	x				The movement of radionuclides through soil formations - Oulman
A-012	4B		x	x	x			Geology of the regolith aquifers of the Nishnabotna Basin - Sendlein, Hussey
A-013	5A		x	x	x			Properties of tile drainage water - Willrich
A-014	4D		x	x	x	x		Influence of geohydrology on landscape and soil formation - Ruhe
A-015	2E		x	x				Laboratory investigation of flow in river bends - Rouse
A-016	5G		x	x	x			Reoxygenation of Iowa streams - Smith, Paulson
A-017	5D				x	x		Feasibility of fish production in tertiary waste treatment ponds - Bechmann
A-018	6A				x	x		Economic analysis of alternative water pollution control measures - Barnard
A-019	6E				x			Model flood plain zoning ordinance - Hines
A-020	2A				x			Energy loss of flow around alluvial-channel bends - O'Laughlin
A-021	5D					x	x	Using soil filtration to reduce pollution potential of lagoon effluent entering gound water system - Beer
A-022	5D					x		Management of cattle feedlot wastes - Dague
A-023	6G					x	x	Waterfowl populations and recreational use patterns in the proposed Saylorville Reservoir area as related to preimpoundment conditions - Haugen
A-024	4C					x		Development of a mathematical model for the simulation of flat-land watershed hydraulics - Johnson
A-025	5D					x	x	Development of pulsating adsorption filter for tertiary treatment of waste waters - Johnson
A-026	2D					x	x	Simulataneous flow of water and heat in water-unsaturated Iowa soils during evaporation - Kirkham

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970						PROJECT TITLE and PRINCIPAL INVESTIGATOR
		5	6	7	8	9	0	
IOWA (continued)								
A-027	5C					x	x	Limnological factors affecting pesticide residues in surface waters - McDonald
A-028	5D					x	x	Effects of limnological factors on water treatment - McDonald, Fisher
A-029	8A					x	x	Effects of river curvature on resistance to flow - O'Laughlin
A-030	2F					x	x	Interrelationship of surface and sub-surface flow in the Nishnabotna drainage basin - Sendlein
A-031	2I					x	x	Use of infrared and other radiation techniques to evaluate drought in Iowa and adjacent areas - Shaw
A-032	5D					x	x	Treatment of aqueous agricultural wastes for clean water and for microbial protein production - Tsao
A-033	6E						x	Rational institutional arrangements for water resource management - Hines
A-034	2J						x	Relationship of hydrology and soils to gully development - Johnson
A-035	6G						x	Effects of stream channelization on fishes and bottom fauna in the Little Sioux River, Iowa - Muncy
A-036	7C						x	Development of model for pricing water in providing a basis for allocating water among competing uses - Timmons
A-037	6B						x	Sociological aspects of water-based recreation in Iowa - Yoesting
B-001	6E		x					Study of operation of the Iowa water permit system - Hines
B-002	2F			x	x	x	x	Ground water seepage patterns to wells for unconfined flow - Kirkham
B-005	6E				x	x		Physical, legal and economic aspects of assessment of costs among drainage districts - Johnson, Hines
B-006	6G			x				Structure of forest bordering the Saylorville impoundment - Landers
B-009	6E				x	x	x	Analysis of the economic implications of the permit system of water allocation - Harl
B-011	6C				x	x	x	Economic analysis of organizations of water users - Meyer
B-013	8A					x	x	Flow of water into tile drains in stratified soils - Toksoz
B-015	6B						x	Development of models for analyzing water resources development and use within a regional framework - Timmons
B-017	6B						x	Determining the demand and economic values of water recreation resources at MacBride State Park, Iowa - Clascock
KANSAS								
A-001	5A	x	x					Evaluation of an index for viral pollution - Loehr
A-002	2F	x	x					Numerical modeling of ground water flow - Weinaug

KANSAS (continued)

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
A-003	2E	x	x					Derivation of continuous basin hydrographs by routing (baseflow component) - Smith
A-004	2G	x	x	x				Integrated soil moisture measurement using radio waves - Eagleman
A-005	3F	x	x	x	x	x	x	Micrometeorological investigations of the energy budget: Effect of summer winds - Jacobs, Bark, Skidmore
A-006	6C		x	x				Methods of financing water resource development - Daicoff
A-007	6B		x	x	x			Value of water for irrigation in the Kansas River Valley - Pine
A-008	5B		x	x	x	x		Pollution from animal feedlots - Larson
A-009	8A		x	x				A study of dissipation devices to control erosion - Haynie
A-010	5F		x	x	x			Chemical removal of nitrate from potable water supplies - O'Brien
A-011	5D		x	x				Water quality changes in confined hog waste treatment - McKinney
A-012	6G		x	x	x			Ecological relationships of organic matter and bacteria in Tuttle Creek Reservoir - Harris
A-013	6G		x	x	x			Trace element chemistry of a small pond in relation to productivity - Armitage, Angino
A-014	5C			x	x	x		Activity patterns of fish exposed to toxic materials - Cairns
A-015	5D				x	x	x	Biological treatment of beef animal wastes to reduce water pollution - Dague
A-016	5B			x	x	x		Nitrate accumulation in Kansas ground water - Murphy
A-017	8A				x			Unsteady flow parameters in hydraulic design - McNown, Yu
A-018	2E				x			Effects of bank seepage on flood hydrographs - Pogge
A-019	5D				x	x		Optimization of step aeration waste treatment processes - Erickson
A-020	5D				x	x		Removal of inorganic material from saline water by precipitation processes - Bricker
A-021	2F				x	x	x	Ground water recharge through pits and wells - Manges
A-022	3F					x	x	Moisture use estimation and relationship between moisture use and nitrogen response in winter wheat - Vanderlip, Murphy
A-023	2A					x	x	Water utilization aspects of weather modification as applied to Kansas - Smith
A-024	2E					x		Longitudinal dispersion of the lower Kansas river Basin - Yu
A-025	2J					x	x	Recent variations in course and regimen, Kansas River and nearby reaches of Missouri River - Dort
A-026	5C					x	x	Effects of pollution, especially from feedlots, on fishes in the upper Neosho river basin - Cross
A-027	5C					x	x	Environmental physiology of fresh-water planktonic crustacea - Armitage
A-028	5F					x	x	A new type of disinfectant for water supplies - Lambert

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
KANSAS (continued)								
A-029	5D					x	x	Experimental optimization of step aeration waste treatment systems - Erickson
A-030	2K						x	Partition coefficients for Fe, Mn, Co, Ni, Zn, Cu, between river water and suspended load - Angino
A-031	5D						x	Use of lime-soda ash sludge for the treatment of municipal wastewater - O'Brien
A-032	6G						x	Photosynthetic production in a turbid reservoir - Marzolf
B-001	5D		x	x				Optimal aeration systems - Erickson
B-003	4B		x	x	x			Storage of fresh water in underground reservoirs containing saline water - Greem
B-007	5B			x	x	x	x	Relationships between pesticidal application and water contamination under irrigation in the Great Plains - Knutson
B-008	4B			x	x			Storage of fresh water in underground reservoirs containing saline water, Phase II-Green
B-010	3F				x	x	x	Evapotranspiration and its chemical reduction - Powers
B-011	4B				x			Numerical modeling of ground water flow - Weinaug, Green
B-015	5G					x	x	Water quality modeling and prediction - Lee
B-018	2F						x	Numerical modeling of unsaturated groundwater flow including effects of evapotranspiration - Green
KENTUCKY								
A-001	6F	x	x	x	x			Economic analysis of alternative flood control projects - James
A-002	5B	x	x	x	x			A study of the persistence of pesticides in impounded waters - Lauderdale
A-003	2F	x	x	x				Factors controlling porosity and permeability in the curdsvelle member of the Lexington limestone - MacQuown
A-004	2D	x	x	x				Mathematical description of transpiration of water as affected by soil, plant, and environmental factors - Walker
A-006	6B		x	x	x	x	x	The economic impact of flood control reservoirs - James
A-007	5C		x	x	x			An ecological study of the effects of strip mining on the microbiology of streams - Weaver
A-008	5D		x	x	x			Chemistry of the oxidant, ferrate, its interaction with specific organics found in waste water - Williams
A-009	2K		x	x	x			Solution geochemistry of the water of limestone terraine - Thraikill
A-010	6B			x	x			Aesthetic and recreational potential of small naturalistic streams near urban areas - Dearinger
A-011	2G			x	x	x	x	Capillary-diffusion and self-diffusion of liquid water in unsaturated soil - Phillips

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KENTUCKY (continued)								
A-012	6E			x	x			Evaluation of the legal institutions of diversion, transfer storage and distribution of water in Kentucky - Tarlock
A-013	5A					x	x	Procedures for trace analysis of dissolved inorganic and organic constituents in water - Christian
A-014	5A					x	x	Analysis of solutions for surface-active constituents - Bauer
A-015	5A				x	x	x	Detection and identification of molecular water pollutants by laser raman spectroscopy - Bradley
A-016	5G				x	x	x	Metabolic role of sulfates and sulfides producing bacteria in the pollution of waters - Aleem
A-017	2D				x	x	x	Plant soil moisture environment and its effect on water movement into plant roots - Haan
A-018	5C				x	x	x	Study of inhibitory compounds produced by fresh-water algae - Harris
A-019	6G				x			A preliminary reconnaissance of areas to be impounded in the Salt River Basin of Kentucky - Krumholz
A-020	6E					x		Systematic study of responses to impending inundations and the directions of impelled population movement - Burdge
A-021	5C					x		Algal growth and decomposition: Effects of water quality - Foree
A-022	6E					x		Anthropological analysis of social and cultural benefits and costs from stream-control measures - Dobyns
B-002	2F					x	x	Unsteady flow toward partially penetrating artesian wells - Huang
B-005	6G					x		A preliminary ecological study of areas to be impounded in the Salt River Basin of Kentucky - Krumholz
B-014	6E						x	Anthropological analysis of social and cultural benefits and costs from stream-control measures, Phase II - Dobyns
B-015	6B						x	Measuring the intangible values of naturalistic streams - Dearinger
B-016	6G						x	A preliminary ecological study of areas to be impounded in the Salt River Basin of Kentucky - Krumholz, Neff, Davis
LOUISIANA								
A-001	6E	x	x	x	x			Study of measures to be taken to accomplish protection of the ground water supply of the Baton Rouge area from degradation due to the intrusion of saline water into area of offtake - Legal aspects, Phase I, Conclusion - Hardy
A-002	4B	x	x	x	x			Fresh water storage in saline aquifers - Kimbler
A-003	5C	x	x	x				Effect of 2-4-dichlorophenoxyacetic acid, and its derivatives, upon the growth of planktonic freshwater algae and its persistence in surface waters - Averitt

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		5	6	7	8	9	0	
LOUISIANA (continued)								
A-004	4B			x	x			Study of measures to be taken to accomplish protection of the ground-water supply of the Baton Rouge area from degradation due to the intrusion of saline water into area of offtake, geological aspects, Phase I, Conslusion - Durham
A-005	2F		x	x				The effect of temperature on the viscosity independent permability of porous media - Greenberg
A-006	4B			x				Feasibility of using air injection to maintain pressure in fresh water aquifers - Hise
A-007	2J				x			Sediment input and dispersal in the Lake Pontchartrain Basin, Louisiana - Ferrell
A-008	2J				x	x		Sediment transportation and bottom configuration, Amite River, near Denham Springs, Louisiana - Gwinn
A-009	3C			x	x	x		Engineering and economic aspects of using sewage effluent for irrigation - Wilson, Beckett
A-010	2K					x	x	Geochemistry of aquifers as affected, or potentially affected and offtake by artificial recharge - Billings
A-011	4B					x	x	Effect of formation dip on the movement of fresh water stored in saline aquifers - Kimbler
A-012	6B					x		An economic evaluation of the Toledo Bend Reservoir project - Stober
A-013	6B					x	x	Disposal of paper mill effluent through irrigation of bottomland hardwood under Louisiana conditions - Wilson
A-014	2H				x	x		A limnological study of Lake Pontchartrain, Louisiana in the summer of 1968 - Stern, Atwell
A-015	9A				x	x		Investigation of manpower resources for water resources research and other water-related activities - Lewis
A-016	6A					x	x	Diverting Mississippi River water to Texas: How will the River be affected? - Kazmann
A-018	6C						x	An economic-hydrological approach to the common groundwater pool problem - Stober
A-019	5B					x	x	The coliform bacteria, plankton, and related physico-chemical factors in Lake Pontchartrain at New Orleans, Louisiana, during the summer of 1969 - Stern
A-020	4B					x	x	Subsidence in the Baton Rouge Area: Its relation to ground-water offtake - Wintz
B-001	4B		x					Measures to protect the ground water supply of the Baton Rouge area from salt water encroachment - Engineering and economic phases - Kazmann
B-002	4B			x	x			Protection of Baton Rouge ground water supply from salt water intrusion, engineering aspects - Conclusion - Kazmann

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LOUISIANA (continued)								
B-003	4B			x				Protection of Baton Rouge ground water supply from salt water intrusion, economic aspects - Conclusion - Sliger
B-004	4B				x	x		Engineering aspects, Phase II: Study of measures to be taken to accomplish protection of the ground water supply of the Baton Rouge Area from degradation due to the intrusion of saline water into area of offtake - Kazmann
B-005	4B				x	x		Economic aspects, Phase II: Study of measures to be taken to accomplish protection of the ground water supply of the Baton Rouge area from degradation due to the intrusion of saline water into area of offtake - Stober
MAINE								
A-001	2G	x	x	x	x			Basic water research on New England soils - Rourke
A-002	5E	x	x					Disposal of agricultural product wastes through the soil - Rourke
A-003	5D	x	x	x				Effect of nitrification of organic wastes on waters in the natural environment - Keshavan
A-004	5D	x	x					Removal of viruses from water - Sproul
A-005	2I	x	x	x	x			Pattern of precipitation dispersion as affected by different vegetative covers in Maine - Schomaker
A-006	5A	x	x	x	x	x		Chemical contaminants found in surface and subsurface water as related to soil and climatic conditions - Struchtemeyer, Epstein
A-007	5B	x	x	x	x	x		Effect of salts applied to highways on the infiltration and percolation of water through the soils banding the highways - Hutchinson
A-008	3E	x	x					Water conservation in food processing - Highlands
A-009	5B		x	x	x			Water quality degradation by wood bark pollutants - Sproul
A-010	2A			x	x	x		Urban hydrologic relationships - Viessman
A-011	5C			x	x	x	x	Water quality - Benthic invertebrate relationships in estuaries - Dean
A-012	2A					x	x	Hydrologic relationships in a coniferous forest - Schomaker
A-013	5B					x	x	Adsorption of viruses on mineral surfaces - Sproul
A-014	5B					x	x	Water quality degradation by septic tank drainage - Hall
A-015	5B					x	x	Causes, effects and control of lake eutrophication - Hall
A-016	5B						x	Phosphate retention by lake sediments - Lotse
A-018	2H						x	Geochemical cycles involving flora, lake water, and bottom sediments - Norton
B-001	5G			x				Feasibility study of a river system as a chemical reactor - Bobalek

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		5	6	7	8	9	0	
MAINE (continued)								
B-003	2K				x	x		Study of a river system as a chemical reactor, Phase II - Bobalek
B-005	5G						x	Phase III, Study of a river system as a chemical reactor - Bobalek, Zabel
MARYLAND								
A-001	2A	x	x	x	x			Simulation of water resources regimes - Cadman, Munno
A-002	5C	x	x	x	x	x	x	Effects of thermal pollution on productivity and stability of estuarine communities - Keller, Stross, Mihursky
A-004	5D	x	x	x	x	x	x	Disposal of wastes from swine feeding floors to minimize or eliminate stream pollution - Green, Schwiesow
A-005	5D		x	x	x	x	x	Treatment of liquid waste from food processing plants - Kramer, Twigg
A-006	5E		x	x	x	x	x	Comparison of various forages for agricultural waste water disposal - Kresge, Axley
A-007	5D		x	x	x	x	x	Improvement of quality of water resources by three-fold attack: Adsorption, sedimentation and mixing - Wockenfuss
A-008	6D		x	x	x			An investigation of factors affecting the intensity of use of water recreational facilities - Volk
A-009	5D			x	x	x	x	Kinetic studies of the oxidative degradation of detergent and related chemical species in aqueous solution - Beckmann, Cook
A-010	6E					x	x	Investigation of the public and private interests in the development of the Chesapeake Bay area - Longest
A-011	5C						x	The thermal requirements and tolerances of key estuarine organisms - Mihursky
A-012	5B						x	Pollution loads in runoff from small agricultural watersheds - Schwiesow
A-013	5G						x	Agricultural processing plant waste water accomodation by forages & soil - Axley
A-014	5D						x	Mechanism of organic adsorption on activated carbon - Cookson
A-015	5C						x	Ecological aspects of aquatic biology through time-lapse photography - Cargo
A-016	5G						x	Physiology of acidophilic bacteria of acid mine waters - Cook
A-017	2F						x	The transient behavior of recharge-discharge areas in regional ground - Ragan
B-001	5G		x	x				Enhancement of recreational uses of estuarine waters through study of potential control methods for stinging nettles - Phase I - Cargo
B-002	5G			x	x			Enhancement of recreational uses of estuarine waters through study of potential control methods for stinging nettles - Phase II - Cargo
B-003	2A				x			Determination of zones of intense contribution to streamflow as related to the concept of partial area contributions - Ragan

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MARYLAND (continued)								
B-005	2A					x	x	Partial area contribution to stream flow - Ragan
B-006	5C					x	x	Water quality criteria to protect the fish population directly below sewage outfalls - Tsai
B-007	6D						x	Effects of economic development upon water resources - Cumberland
MASSACHUSETTS								
A-001	6B	x	x	x	x			A survey and evaluation of small artificial recreational ponds in central Massachusetts - McCann
A-002	6G	x	x	x				The ecology of the young fishes of the Weweantic River estuary - Cole
A-003	3B	x	x	x	x	x		Hydrological studies in Massachusetts - Higgins
A-004	5B	x	x	x				Pilot study of the occurrence and characteristics of shallow aquifer contamination in Massachusetts - Motts
A-005	3F	x	x	x				Development of methods for increasing efficiency of water use in cranberry culture - Norton
A-006	5G	x	x					Relation of sediment load to hydrological characteristics of Connecticut River between Northfield and Springfield, Massachusetts - Hayes
A-007	5A	x	x	x				The ecological significance of cellulolytic bacteria in Quabbin Reservoir - Reynolds
A-008	5B	x	x	x				Adsorption of pesticides on earth materials - Baker
A-009	5D	x	x	x	x	x	x	Closed systems for animal sewage treatment - Clayton
A-010	5C	x	x	x				Pesticide occurrence, concentration, and degradation in free water systems - Miller
A-011	5C	x	x	x				Effects of organic deposits on water quality in impoundments - Feng
A-012	1B		x	x				Thermodynamic relationships within the system "sediment-water-air" - Zajicek
A-013	5C		x	x				The effects of climate upon the work capacity and cardiac and opercular cycles in fresh-water fish - Roberts
A-015	3F		x	x				Subsurface irrigation of turf areas - Nozzle design and spacing - Whitney
A-016	8A		x					Small watershed storage increase using low dams - Hendrickson
A-017	2D		x	x				The mechanics of fluid transport in vegetation - Harris
A-018	5G				x	x	x	Arrest of aging process in Massachusetts lakes resulting from man's activities - Litsky
A-019	5B				x	x		Impact and fate of pollution in estuarial waters - Cole
A-020	5D				x	x	x	Microbial degradation of organic pollutants of industrial origin - Gunner

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
MASSACHUSETTS (continued)								
A-021	4B				x	x	x	Optimum utilization and management of water in formations hydrologically connected to a stretch of the Connecticut River - Motts
A-022	6E			x				Attitudes of local decision-makers toward water pollution abatement in selected Massachusetts communities on the Connecticut River - Shanley
A-023	2C				x	x	x	The role of aquatic vascular plants in the eutrophication of selected lakes in western Massachusetts - Livingston
A-024	6B					x	x	Evaluation of discontinuities in regional population projections - Lee
A-025	6E						x	A legal and economic evaluation of ground water use in Massachusetts - Forste
A-026	2I					x	x	A study of the relationship of the vascular plant flora and vegetation of the Mill River and its floodplain in Northampton and Williamsburg, Massachusetts, to patterns of land use and to the presence of the family - Robinton
A-027	6A					x	x	Surface waters of a small city (Springfield, Mass.), Phase II - Brainerd
A-028	2L						x	Water resources potential of an urban estuary - Cochrane
B-003	6E				x	x	x	Institutional patterns for evolving regional programs for water resource management - Howards
B-004	6A				x	x	x	Programmed selection of optimum uses of a small water resource subjected to complex simultaneous demand stresses - Carlozzi
B-005	8C				x	x	x	Control of benthic deposits in lakes - Feng
B-006	5G				x	x	x	Microbial intervention in the eutrophication process - Litsky
B-008	2A					x	x	Watershed response to hydrologic influences - Higgins
B-010	6G					x	x	Enhancement of ecologic and aesthetic values in wetlands associated with interstate highways - Carlozzi
B-011	6A					x	x	A methodology for planning optimal regional waste management systems - Adrian
B-012	6G						x	A multi-variate model for public management of freshwater wetlands - Larson
B-014	6A						x	Planning for capacity expansion of water distribution networks - Schaake
B-015	6B						x	An urban river in its changing culture - Sinton, Carlozzi, Noyes, Wetherbea
MICHIGAN								
A-001	4B	x	x	x				Groundwater recharge, dynamics of groundwater flow systems - Hinze
A-002	4B	x	x					Ground water and bedrock surface delineation in southeastern Michigan - Mozola
A-003	2G	x	x	x				Water movement in unsaturated soils - Kunze
A-004	3F	x	x	x				Microclimatic modification by water spray - Harrington

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970						PROJECT TITLE and PRINCIPAL INVESTIGATOR
		5	6	7	8	9	0	
MICHIGAN (continued)								
A-005	6A	x	x					Application of systems and optimization analysis to water quality problems in Michigan - Milstein
A-006	4B	x	x	x				Seasonal movement of percolating waters to the ground-water table under hardwood forests in Michigan - White
A-007	5D	x	x					Biological recovery of waste water - Schulze
A-008	5C	x	x					Toxic action of water soluble pollutants on freshwater fish - Fromm
A-009	2B	x	x	x				Determination of intensity-duration-frequency-areas coverage of intense summertime storms - Wheaton
A-010	5C	x	x	x				Biotic response to pollution reduction in a river - Lauff, Knight
A-011	4B			x	x			Ground-water resources and bedrock surface delineation of southeastern Michigan - Mozola
A-012	5B			x	x	x		The relationship of sewage handling practice to pesticide residue levels and invertebrate ecology - Zabik
A-013	5D			x	x	x		Fluidized exchange systems for removal of nitrogen and phosphorous from waste-water - Weber
A-014	5C				x			The effects of limnological factors on the uptake of 137 Cs by fish - Kevern
A-017	3B				x			The hydrologic role of various upland hardwood forest humus types in the Lake States region - White
A-018	8A				x			Computer aided design of waste water collection and treatment systems - Deininger
A-019	8A				x			Characteristics of interface flow in subsurface disposal systems - Santeford
A-020	6B				x			Preliminary investigation of the water resources of Isabella County, Michigan, as represented by farm ponds - McNeel
A-021	5D				x			Tertiary treatment using diatomaceous earth and activated carbon - Dirasian
A-022	4B				x			Attenuation of selected nitrogen forms by sorption from solution onto natural soils - Stephenson
A-023	6A				x	x	x	Watershed analysis relating to eutrophication of Lake Michigan - Stephenson
A-024	6A					x		Dynamic system modeling and simulation of a river basin - Coulman
A-025	6G					x		Interrelations of several abiotic factors and the higher aquatic plants of a stream ecosystem - Kullberg
A-026	5D					x		An attempt to detect highly diluted viruses in waters by flocculation - Mack
A-027	5A					x		Occurrence of prosthecate bacteria in a gradient-polluted river - Staley
A-028	2I					x		Metamorphosis of snowpack profiles and changes in water storage following strip cutting in pine forests in Michigan - White

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970						PROJECT TITLE and PRINCIPAL INVESTIGATOR
		5	6	7	8	9	0	
MICHIGAN (continued)								
A-029	5C					x	x	Long-term effects of pesticides on aquatic invertebrates - Bender
A-030	5C					x		Response of aquatic organism populations to nutrient increase - Cooper
A-031	5D					x	x	Rate of nitrogen and phosphorus stripping form sewage lagoons by aquatic angiosperms - McNabb
A-032	4C					x		Trophic dynamics of a woodland stream ecosystem - Cummins
A-033	5A						x	Development of an instrumental combustion method for the rapid determination of total phosphorus in aqueous solutions - D'Itri
A-034	5A						x	Studies on algae from eutrophic and oligotrophic waters and their use in bioassay of water quality - Moss
A-035	5B						x	Uptake of insecticides by freshwater mussels and effects of sublethal concentrations of insecticides on these mussels - Zabik
A-036	6B						x	An engineering economic study of reclamation and multiple reuse as a water supply alternative - Weber
A-037	5B						x	Nitrification in surface waters - Baillod
B-002	2A			x	x			A principal investigation of the combined hydrological and mass budget of a critical glacier basin - Miller
B-006	4B				x	x	x	Application of seismic shear wave studies to the investigation of aquifers - Bennett, Hinze
B-007	4B				x	x		Geochemical investigation of the groundwater system in the Lansing, Michigan area - Romberger
B-008	6G						x	Predicting variations in energy flow through a semi-controled lotic ecosystem - Cummins
B-009	5C						x	Phytoplanktonic nitrogen as an index of cultural eutrophication - Wetzel
MINNESOTA								
A-001	4A	x	x	x	x			Effect of pothole drainage upon ground water resources - Manson
A-004	4A	x	x	x				Factors influencing soil freezing in forests and the importance of their effect of surface runoff - Thorud
A-006	2G	x	x	x	x			Water adsorption and its interactions with clay and quartz - Blake
A-007	5A	x	x	x				Studies on the use of planktonic desmids as indicators of the trophic status and water quality of freshwater lakes - Brook
A-008	5B	x	x	x				Water quality, organic productivity, and the distribution of organisms in Minnesota lakes - Wright

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
MINNESOTA (continued)								
A-009	4B		x					Ground-water contribution of streamflow and its relation to hydrogeologic basin characteristics and recharge rates to aquifers in Minnesota - Ackroyd
A-010	2F	x	x					Analysis of factors affecting aquifer test results under induced streambed infiltration conditions with electric analog computers - Walton
A-011	5C	x	x	x	x	x		A study of the open water distribution and abundance of net plankton as an index of the eutrophication in Lake Superior - Olson
A-013	4A		x	x	x			Review and analysis of precipitation and runoff data for selected watersheds in Minnesota - Bowers
A-014	2F			x				Recharge from induced infiltration under varying stream stage and aquifer water-level conditions - Walton
A-015	6E				x	x		Hydrologic aspects of water laws in Minnesota - Walton, Haik
A-016	5C				x	x	x	Primary productivity of Minnesota lakes - Wright
A-017	2A				x	x	x	Effects of areal and time distribution of runoff supply on watershed hydrographs - Larson
A-018	5G				x	x	x	Methodology for integrating water quality management with the management of the total water resources in Minnesota - Straub
A-019	6B					x	x	Economics of water quality control in the upper Mississippi River, Minnesota - Waelti
A-020	2E					x	x	Evaluation of selected computer programs in hydrology - Bowers
A-021	6E						x	Water resources administration in Minnesota - Walton
A-022	5C						x	Zooplankton biomass and incipient eutrophication in Lake Superior - Olson
B-001	5C		x	x				Diatoms and zooplankton in Minnesota lakes - Wright
B-002	4A		x	x	x			The effect of the natural sealing of potholes upon water movement and ground water resources - Manson
B-003	5E		x	x	x	x		Storage and movement of water in soils as related to spacial and time changes in the clay-quartz matrix - Blake
B-005	4A		x	x	x			Vertical migration of moisture in the soil induced by winter thermal gradients and its influence upon spring water resources - Baker
B-007	2A		x	x	x	x		Study of factors affecting the channel phase of runoff from small watersheds by mathematical modeling - Larson
B-009	2H				x	x	x	Relation of phosphorus in lake-bottom deposits and pollutional history of Minnesota lakes - Shapiro

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
MINNESOTA (continued)								
B-010	5C				x	x		Study of techniques for determining changes in phytoplankton populations in clouds of fluorescent dye moving in the Mississippi River - McNabb
B-012	5B					x	x	Development of a mathematical model to predict the role of surface runoff and ground water flow in overfertilization of surface waters - Straub
B-013	2D					x	x	Reduction of water stress in crop production by mist irrigation - Nylund
B-015	2G					x	x	Characteristics of the soil matrix that affect water storage and movement - Blake
B-020	6G						x	Pollution and the ecology of near-shore periphyton of Lake Superior - Olson
B-031	6B						x	Participating ecology: A study of citizen's groups involved at the grass roots to improve the water resources environment - Gerlach
B-032	6G						x	Mississippi River ecology associated with heated power plant effluent - Hopwood
MISSISSIPPI								
A-001	8A	x	x					Precipitation probabilities in Mississippi - McWhorter
A-002	6B	x	x					Water resource characteristics of the Town Creek Watershed as an attraction for industrial users - Peden
A-003	5F	x	x	x				Factors affecting the removal of iron and manganese from ground water - Robinson
A-004	5F	x	x					Decontamination of low-level radioactive wastes with yazoo and zilpha clays - Middlebrooks
A-005	4A	x	x					Ground water regulation in the coastal flatwoods of Mississippi - Miller
A-006	6E	x	x					Law of water resources of the State of Mississippi: A multifactoral, policy-oriented study of legal prescriptions relating to water use and control - Vinson
A-007	5D	x	x	x				The effect of temperature upon the microflora of sewage during aerobic treatment - Brown
A-008	6E	x	x					Local action and acceptance of watershed development - Wilkinson
A-009	3B	x	x	x				An inventory and study of beaver impounded water in Mississippi - Arner
A-010	8A			x	x			Rainfall intensity, frequency and duration for station and area storms with varying antecedent precipitation - McWhorter
A-011	6D			x				The availability of water for industrial uses in selected small communities in Mississippi - Peden
A-012	5F			x				Decontamination of low-level radioactive wastes from yazoo and zilpha clays, Phase II - Middlebrooks
A-013	3F			x	x	x		Forest site amelioration in the coastal flatwoods of Mississippi economic and biological considerations - Miller

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		5	6	7	8	9	0	
MISSISSIPPI (continued)								
A-014	6E			x				The law of water pollution control-Williams
A-015	6A			x				Sociological factors in watershed development - Wilkinson
A-016	6C				x			An analysis of alternate methods of financing types of water resource facilities in Mississippi - Peden
A-017	6A				x			An economic philosophy for selecting a rational structural design for hurricane protection - Williams
A-018	5B				x			The microbiology of ground water recharge - Brown, Tischer
A-019	6B				x			Application of sociological theory to selected problems of community water resources development - Wilkinson
A-020	6G				x			A quantitative study of invertebrates found in certain wetland plant communities in Mississippi - Arner
A-021	2F				x			Application of moments to mapping the vertical variability of the aquifer systems in Mississippi - Keady
A-022	3F				x			The infiltration of irrigation water into the soil - Vaigneur, Fox
A-023	2J				x			Mechanism of stream meandering - Shindala
A-024	8A					x		The flow of water in flumes and canals - McWhorter
A-025	6C					x		An analysis of pricing practices and policies of water service utilities in small communities in Mississippi - Peden
A-026	6B					x		The impact of reservoirs on land values: A case study - Williams
A-027	5C					x		The decomposition of petroleum products in our natural waters - Brown
A-028	6E					x		Community involvement of participants in watershed planning - Wilkinson
A-029	6G					x		An ecological and recreational use survey of a small Mississippi River just before channelization - Arner
A-030	2J					x		Changes in natural channels resulting from control devices in the upper reaches of the basins - Shindala
A-031	6E					x		Political processes in the promotion of water resource development programs - Jones
A-032	6B						x	An analysis of the relationship between the availability of port facilities and industrial growth in selected inland waterway port cities in Mississippi - Peden
A-033	6B						x	The importance of water related activities at state parks in Mississippi - Williams
A-034	5C						x	The effect of salinity on the oxidation of hydrocarbons in estuarine environments - Brown

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970						PROJECT TITLE and PRINCIPAL INVESTIGATOR
		5	6	7	8	9	0	
MISSISSIPPI (continued)								
A-035	6B						x	Community orientations of leaders in local water resources action - Wilkinson
A-036	6G						x	A study of the aquatic ecosystems of two national waterfowl refuges in Mississippi - Arner
A-037	5B						x	Thermal gradients associated with discharge of heated effluents - Shindala
A-038	2F						x	A study of the hydrochemical facies of the Wilcox Aquifers in Mississippi - Keady
A-039	6A						x	A systems approach for the study and control of factors affecting water pollution - Razek A-Nour
A-040	5E						x	Forage crop irrigation with oxidation pond effluent - Allen
B-002	2G			x	x	x	x	The effect of temperature on water flow in soils - Jensen
B-005	6E						x	Organization, development and management of community water systems in rural areas - Singh
B-006	6E						x	A case study in the formulation of a water resources management plan - Peden
MISSOURI								
A-001	4B	x	x	x	x			Availability, distribution, quantity and quality of water resources in carbonate karst terrain - Maxwell, Gevecker
A-002	6A	x	x	x				Systems approach to river basin development - Ray
A-003	4A	x	x	x				Determination of yields of water to be expected from different land areas in Missouri for the climatic patterns characteristics of the areas - Woodruff
A-004	5C	x						Water quality alteration through acid and heat pollution in a 1500 acre reservoir - Campbell
A-005	5G	x						Biochemical capabilities of surface film and benthic bacteria in fresh-water systems - Barnekow
A-006	7B		x	x	x			The use of lightweight particles for discharge measurement in open channels - Liu
A-007	5C			x				The role of heterotrophic biotic populations in reducing organic contaminants added to natural waters - King
A-008	6E			x	x	x		An evaluation of alternatives for water resources regulation in Missouri - Lauer
A-009	5A				x			A quantitative study of trace elements on abiotic and biotic aggregates in the Missouri River -Lott
A-010	5D				x			Effects of audio vibrations on aerated biological systems - Hemphill
A-011	5C				x			The ecology of stream biota in waste assimilation - King

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
MISSOURI (continued)								
A-012	1B				x	x	x	A study of the interactions present in aqueous salt solutions by nuclear magnetic resonance spectroscopy - Larsen
A-013	2A					x		Hydrologic and photogeologic determination of rainfall, runoff, and groundwater relationships in a dolomite area - Gevacker
A-014	5A					x		Spectrophotometric and fluorometric determination of selected anion water contaminants - Guyon
A-015	5F					x		Dynamic separation of suspended solids - Hjelmfelt
A-016	5B					x		Sorption and desorption of chlorinated hydrocarbon pesticides in aquatic sediment minerals - Huang
A-017	2J					x		Non-equilibrium transport of suspended sediment - Lenau
A-018	6A					x		An economic analysis of the public water supply district - McNabb
A-019	2A					x		Seasonal shallow storage and deep seepage components for the hydrologic budget of a small forested Ozark watershed - Settergren
A-020	5C					x	x	The evaluation of environmental alteration by thermal loading and acid pollution in the cooling reservoir of a stream electric station - Witt
A-021	5C					x		Stream pollution in the "new lead belt" of southeast Missouri - Wixson
A-022	1B					x	x	NMR and X-ray studies of structure in aqueous electrolyte solutions - Larsen
A-023	5B						x	Geochemical effects of mining pollution of the streams of SE Missouri - Bolter
A-024	5A						x	Automated potentiometric techniques for the on-site monitoring of ions imported in water quality control - Manahan
A-025	8A						x	Spillway design floods for small dams in rural Missouri - Harbaugh
A-026	5F						x	Development of neutron activation techniques for investigation of water clarification - Hemphill
A-027	6E						x	An evaluation of legal theories currently employed to determine which lands are riparian - Levi
A-028	8A						x	Evaluation of a single layer of graded gravel as a protective filter on embankment slopes - Muir
A-029	5D						x	Removal of phosphates by sorption on activated alumina - Purushothaman
A-030	1B						x	The effects of herbicides, pesticides, and fertilizers on the optical properties of water - Querry
B-001	5C		x	x				The effects of heated water, acid mine drainage and alkaline ash drainage on water quality and community metabolism of a 1500 acre reservoir - Campbell
B-002	4B		x	x				Geochemistry and origin of sulfo-saline ground water, Saline County, Missouri - Carpenter, Miller

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
MISSOURI (continued)								
B-004	4B		x	x				Drilled well investigation of dolomite aquifer characteristics - Maxwell
B-005	4A		x	x				Availability of sub-surface water in Missouri for consumptive use by plants - Decker, Scrivner
B-007	2E		x	x				Investigation of the spatial behavior of roughness in laboratory watersheds under conditions of spatially varied unsteady flow - Harbaugh
B-011	6B	x	x	x	x			Economic aspects of supplemental irrigation in Missouri - Burt
B-015	5D			x				Effect of surfactant micelles on metal ion removal by flotation from metallurgical wastewater - Venable
B-017	5D				x	x	x	Effect of surfactant micelles on metal ion removal by flotation from metallurgical wastewater, Phase II - Venable
B-018	5A				x			Spectrophotometric and fluorometric determination of selected anion water contaminants - Guyon
B-019	2A				x	x		Spatial behavior of roughness in laboratory watershed, Phase II - Harbaugh
B-021	5C				x	x	x	Impact of lead-zinc mining on the quality and ecology of surface waters in southeast Missouri - Bolter
B-022	2G					x	x	Thickness of soil solum as a parameter of plant-available water storage capacity in soils underlain by carbonate rocks - Scrivner
B-023	5A					x	x	Automated potentiometric techniques for the on-site monitoring of anion concentrations in water - Manahan
B-037	5B						x	Sorption and desorption of chlorinated hydrocarbon pesticides in aquatic sediment minerals, Phase II - Huang
MONTANA								
A-001	4A	x	x					Water resources of Montana: Basic hydrologic studies of two selected Montana watersheds - Williams
A-002	6B	x	x					Problems and opportunities of water resources utilization in the upper Columbia and Missouri River basins - Holje
A-003	7B		x					Ground water resources of Montana - Groff
A-004	4A		x					Water, soil, and plant relations - Behan
A-005	5G		x					Water quality in Montana - Solberg
A-006	7B			x	x			Evaluation of hydrologic instrumentation on Maynard Creek watershed and selection of watersheds for intensive engineering studies - Williams, Stauffer
A-007	7B			x	x	x	x	Mountain precipitation and distribution - Super

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MONTANA (continued)								
A-008	7B			x	x	x	x	Hydrologic analysis of the North Fork of Elk Creek - Blake, Konizeski
A-009	6B			x	x	x		Problems and opportunities of water resources utilization in the upper Columbia and Missouri River Basins - Holje, McConnen
A-010	6E			x				Study of Montana water law codes - Stone
A-011	4B			x	x			Hydrogeology of the Great Falls area - Groff
A-012	4B			x	x	x		Inventory and evaluation of the ground-water resources of Summit Valley and upper Silver Bow Creek drainage area - Botz
A-013	7B			x	x			Application of geophysical instruments and procedures to ground water research - Botz
A-014	7C			x	x	x		General studies related to coding ground-water appropriations and basic data for information, storage and processing systems - Groff, Botz
A-015	7B			x	x	x		Transpiration rates of conifers - Taber, Behan
A-016	2I			x	x	x		The aquatic plant resources of western Montana - Preece
A-017	6G			x	x	x		Natural water systems in western Montana - Solberg
A-018	4C			x	x			Effect of logging on small stream fisheries - Weisel
A-019	5G			x	x	x	x	A geologic, geochemical and microbiologic study of Flathead Lake - Taylor, Silverman
A-021	7B				x			Operation of the bridger data acquisition system and the data recording center - Weaver
A-023	2F				x			Gravity investigation of water-bearing strata in Swan Valley, Montana - Crosby
A-024	6E				x			Community water problems as a factor in municipal incorporation in Montana - Waldron
A-025	2A				x	x		Computer simulation of the hydrologic system of a mountain watershed - Dunn
A-026	6B					x		A study of water resources research needs in Montana - Bradley
A-027	5A				x	x	x	Microbiological studies in an open and closed watershed - Walter
A-028	2A				x	x		Water resources in Sourdough and Middle Creek Watersheds: A comparative study of quality and hydrology - Sanks
A-029	5A					x	x	Hydrogeochemical investigation of selected watersheds in southwestern Montana - Miller
A-030	6B					x		Water and recreation use, Blackfoot River drainage, western Montana - Malouf
A-031	6E					x	x	Legal research, writing and drafting toward improving Montana water laws - Stone
A-032	5C				x	x		Copper toxicity on algae of the Big Blackfoot River - Sheridan
A-033	6B						x	Planning for multiple purpose water resources development: A case study of the Bitterroot Valley as it relates to a state water plan - Holje

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MONTANA (continued)								
A-034	2A						x	Comparison of field measurements to computer model results for Montana watersheds - Dunn
A-035	2F						x	Investigation of the use of chloride from precipitation as a ground-water tracer - Botz
A-036	2F						x	The role of deformation in changing the reservoir properties of aquifers - Crosby
A-037	5C						x	Sculpins and sculpin parasites as indicators of stream quality - Canaris
A-038	5C						x	Testacea (Protozoa: Sarcodina) as indicators of water quality in western Montana - Tibbs
A-039	2I						x	The competition for soil water by native Montana grasses - Eddleman
A-040	5B						x	The fate and effects of pesticides in the aquatic environment of the Flathead Lake drainage area - Gaufin
B-002	7B		x					A proposal to study hydrological data acquistion through remote reconnaissance systems - Ward, Gerlach
B-003	8A		x	x				The nature of snow cornice accumulation on a mountain ridge and devices for prevention or control of these features in the northern Rocky Mountains - Montagne, Super, Townes
B-004	6E		x	x				Administrative arrangement for water resources development - Sheridan, Holje
B-006	7B		x					Instrumentation of remote areas - Weaver
B-009	5A		x	x				Industrial organic micropollutants and protozoa - Rowan
B-011	4A			x	x			Determination of plant rooting and water absorption patterns and their affects on watershed runoff - Nimlos
B-014	7B			x	x	x	x	Digital instrumentation and telemetry for water resources research - Weaver
B-024	2F					x	x	Water dating techniques as applied to the Missoula ground-water reservoir Montana - Konizeski
B-025	7B				x	x	x	Hydrological data acquisition through remote reconnaissance systems - Gerlach
B-029	6A					x	x	Development of a state water planning model - Boyd, Williams
B-031	2J						x	Siltation rates and life expectancies of small, headwater reservoirs in Montana - Konizeski
NEBRASKA								
A-001	3F	x	x	x	x	x		Energy sources for evapotranspiration in the plains region - Rosenberg
A-003	3F		x	x	x	x		Engineering phases of land treatment related to increasing water use efficiency and storage efficiency of rainfall - Wittmuss

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NEBRASKA (continued)								
A-004	6D		x	x	x	x	x	Input-output analysis of water use for Nebraska industries - Epp
A-005	7B		x	x	x	x		Internal water status of plants - Eastin, Sullivan, Kinbacher
A-006	6E		x	x				Mechanics of bank seepage in natural streams during flood flows - Sarpkava
A-007	5F		x	x	x	x	x	Brackish water purification by biological fuel cell-powered electrodialysis - Scheller
A-008	6E		x	x	x	x		A legal-economic analysis of administrative and market procedures used in the transfer of water rights - Fischer, Baker
A-009	6E			x				Eminent domain - Harnsberger
A-010	3A			x	x			Surface properties of teflon film in saline water processes - Tao
A-011	4B			x	x	x	x	Utilization of the storage potential of river valley aquifer - Marlette, Directo
A-013	6E					x	x	Conjunctive use of ground and surface waters - Harnsberger
A-014	5G						x	Eutrophication of small reservoirs in the Great Plains - Hammer
A-015	2D						x	Physiological and biochemical responses of plants to different internal water potentials - Kinbacher
A-016	6B						x	Economic and technical aspects of the use of mathematical models in state water resources planning programs - Viessman
A-017	3F						x	Evaluation of methods for improving water use efficiency through simultaneous determination of field evapotranspiration and photosynthesis - Rosenberg
B-003	5G						x	Animal waste utilization for pollution abatement - Cross
NEVADA								
A-001	4B	x						Chemical and physical aspects of mountain and mining hydrology - Mifflin
A-002	4A	x						Evaluation of drainage problems in waterlogged areas and bolsons - Kashef
A-003	7B	x						Analog computer components - Maxey
A-004	6D	x	x					Demand for water-based recreational activities in Nevada - Wyckoff, Myles
A-005	3F	x						Preliminary survey of water quality and soil characteristics for irrigation in Nevada - Bourns
A-006	7B		x					Transpiration of plants under natural conditions - Went
A-007	7B		x					Hydrologic aspects of pre-lahontan sediments in Nevada - Mifflin
A-008	5F		x	x				An engineering-economic model for waste-water reclamation and re-use - Orcutt
A-009	4B		x	x				Detailed investigations of ground-water flow systems in Nevada - Mifflin
A-010	7C		x	x				Nevada water resources data center - Maxey

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970						PROJECT TITLE and PRINCIPAL INVESTIGATOR
		5	6	7	8	9	0	
NEVADA (continued)								
A-011	4A		x					Humboldt River surface water analysis - Maxey
A-012	7C		x					Evapotranspiration map of the State of Nevada - Maxey
A-014	4B			x				Static and dynamic models of ground-water development and use in Nevada - Domenico
A-015	6C			x				Effect of quality factors on the demand for water-based recreation - Myles
A-016	2G				x			Pore-water pressure distribution in confining layers in the vicinity of a pumping well - Domenico
A-017	2F				x			Statistical treatment of hydrogeologic data, Part I, Hydrochemical aspects - Sharp
A-018	2A				x			Atmospheric moisture balance study - Stidd
A-019	6B				x			A quantitative analysis of socio-economic factors affecting water-based recreation - Myles
A-020	2G				x			Factors restricting infiltration rates on decomposed granitic soils - Fletcher, Skau
A-021	2A				x			Hydrologic responses to climate of closed basins in the Great Basin - Mifflin
A-022	2F				x	x	x	Chemical and flow regimes of Great Basin Springs - Sharp, Mifflin
A-023	2D				x			The water relations of desert plants - Stark
A-024	2F					x		Statistical treatment of hydrogeologic data, Part II - Sharp
A-025	2G					x		Factors restricting infiltration rates on decomposed granitic soils, Phase II - Morris
A-026	2A					x		Precipitation and runoff distributions, analysis and comparisons - Stidd
A-027	2H					x		Ecology of schistosome dermatitis in western and northern Nevada waters - Church
A-028	6E						x	Social values in relation to water resources policy - Roelofs
A-029	2A						x	Precipitation and runoff distribution analysis - Stidd
A-031	2G						x	The effect of irrigation management on soil-water relationships in stratified soils - Guitjens
A-032	6B						x	A survey of data and criteria for development of water coefficients for use in economic analysis - Malone
A-033	4A						x	A study of the relationships between stream-water quality and watershed characteristics - Morris
B-001	3F		x					Evaluation of parameters of irrigation water usage in Nevada, Phase II - Bourns
B-004	4B		x					Conjunctive use of ground water and stream flow in Humboldt River basin, Nevada - Phase I - Maxey, Shamberger
B-005	6A	x						Analog computer for hydrologic research - Maxey, Domenico
B-006	4B	x	x					Delineating ground-water flow systems in Nevada - Maxey, Mifflin
B-007	4B	x						Applicability of conjunctive use of ground and surface waters - Maxey, Domenico

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	 6	 7	 8	 9	 0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
NEVADA (continued)								
B-008	2B	x	x					Analysis of statistical studies of precipitation data - Stidd
B-009	7B	x	x					Analysis of water and rock samples by atomic absorption - Weyler
B-010	4B	x	x					Recycling of water in Las Vegas ground-water basin - Orcutt
B-011	3F	x	x	x				Evaluation of parameters of irrigation water usage, Phase I - Bourns
B-012	7B	x	x					An infiltrometer for rain and snow events - Skau
B-013	3F			x				Evaluation of parameters of irrigation water usage, Phase III - Gifford
B-014	4B			x	x			Conjunctive use of ground water and stream flow in the Humboldt River basin, Nevada, Phase II - Maxey
B-019	2K				x	x		Dissolved constituents of natural waters: Contributions from mineralized areas - Sharp, Bonham
B-023	6E					x	x	State water law orientation toward scientific and technological bases for effective planning and management - Ohrenschall
B-024	6A					x	x	The optimum release policy for a multi-purpose reservoir using stochastic hydrology-Butcher
B-028	2A					x		An atmospheric energy budget study - Stidd
B-036	2K						x	Dissolved constituents of natural waters: Contributions from mineralized areas, Phase II - Sharp, Bonham
B-038	6A						x	Optimal basin development and water allocation with consideration of restricted water supply conditions - Cochran, Fordham, Friesen
NEW HAMPSHIRE								
A-001	4B	x	x	x				Relationship of yield of ground water from drilled wells and types of bedrock in New Hampshire - Stewart
A-002	2K	x	x	x	x			Chemical character of ground and surface waters in relation to soil weathering processes - Hall, Prince
A-003	5A	x	x	x				Atomic fluorescence spectroscopy - A potential tool for trace analysis - Ellis
A-004	5G	x	x	x	x	x	x	Impact of copper sulfate treatment on some of the limnological characteristics in Winnisquam Lake, Belknap County - Sawyer
A-005	5B		x	x	x			Nitrogen content of drainage water, litter and soils in the vicinity of alder and white pine tree sites - Peterson
A-007	5D		x	x	x			Numbers and types of microorganisms in stabilization of pond effluents - Slanetz
A-008	6D		x	x	x			An economic analysis of water supply and demand in the Piscataqua River watershed - Forste

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
NEW HAMPSHIRE								
A-009	5A		x	x	x	x	x	Analysis of aromatic constituents in water using fluorescence and phosphorescence, Phase I and Phase II - Ellis
A-010	5A		x	x	x	x		A study of algal populations associated with different levels of water quality in New Hampshire - Mathieson
A-011	6E			x	x	x		A compendium of water law and economics in New Hampshire - Forste
A-013	5C				x	x	x	An investigation of Aphanizomenon flos-aquae, a toxic by-product of eutrophication - Sawyer
A-014	5A				x	x	x	Detection and enumeration of virus in natural waters - Metcalf
A-015	4A				x	x	x	The influence of wetlands on quantity and quality of stream flow - Hall, Byers
A-016	2F					x	x	Occurrence and characteristics of fractures in crystalline rocks of southeastern New Hampshire and their relationship to the yield of drilled water wells - Stewart
A-017	5A					x		Utraviolet absorption and its possible relation to eutrophication in large New Hampshire lakes - Normandeau
A-018	6D					x	x	Estimation of household consumption of water - Andrews
A-019	5C						x	A study of algal populations associated with different levels of water quality in New Hampshire, Phase II - Mathieson
B-001	5C				x			Some effects of sub-lethal levels of DDT in the freshwater environment - Sawyer
NEW JERSEY								
A-001	6E	x	x	x				Water law of New Jersey - Morreale
A-002	7C	x	x	x				Drought frequency, intensity and duration: Its correlation to streamflow, and its impact upon synthetic hydrology - Snow
A-003	5G	x	x	x				An investigation of analog computer simulation of stream pollution dispersion models with chemical reactions - Davidson
A-004	5D	x	x					Water conservation through filtration of gelatinous sludges in industrial waste treatment - Dittman
A-005	2E	x	x	x	x			Turbulent dispersion in water flow systems - Peskin
A-006	4B	x	x					Petrology of aquifers of New Jersey coastal plain - Martens
A-007	4B	x	x					Water well yields in the New Jersey highlands in relation to geologic environment - Smith
A-008	3B	x	x					Vegetation influences on water yield on the Labanon Forest experimental watersheds - Buel
A-009	4C	x	x	x	x	x	x	Hydrology of suburban areas - Nathan

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
NEW JERSEY (continued)								
A-010	6D	x	x	x	x	x		Industrial water and waste disposal requirements - Dutta, Granstrom
A-011	4B	x	x					Hydrologic analysis of the Millstone River Basin, New Jersey - Dewiest
A-012	5A		x					Evaluation of phenol water quality - Faust
A-013	6B		x					Preliminary investigation of the perception of flood hazard in the Delaware Valley-Beyer
A-014	6B			x	x			Economic basis for water resources analysis - Whipple
A-015	5D				x	x		Organic concentration gradient in an aeration column - Known
A-016	6E				x	x		Effectiveness of governmental action for water pollution control in New Jersey - Burch
A-017	5G			x	x	x		Engineering applications of distributed and maltivariable system theory to the dynamics of water pollution control - Perlis
A-018	4B					x		Development of the Mullica River Basin - Granstrom, Durand
A-019	5B				x	x	x	Analysis of thermal pollution dispersion - Ahlert
A-020	5A				x	x	x	Recovery, separation, and identification of phenolic compounds from polluted waters - Faust
A-021	5D					x	x	Removal of phosphate from water by aluminum and iron - Hsu
A-022	5D					x	x	Purification of low quality waters by foam separation - Wilson
A-025	5D					x	x	Dynamics of biochemical oxygen demand - Whipple
A-026	2B						x	Investigation of the effects of urbanization on precipitation type, frequency, areal and temporal distribution - Shulman
A-027	5B						x	Potential contribution of fertilizers to water pollution - Douglas
A-028	7B						x	Hydrodynamics of storm sewers - Bourodimos
A-029	6E						x	Water supply in New Jersey: Policies and politics in an urban state - Baker
B-001	6D			x	x	x		Changing technology and industrial water requirements - Granstrom
B-002	6D			x	x	x	x	Urbanization and its effect on water resources - Marcus, Newling, Faust, Whipple
B-005	5G			x	x			Artificial mixing of density-stratified fluids - Brush
B-006	3B			x	x	x	x	Use of water by lowland vegetation in the New Jersey coastal pine region - Buel
B-007	6F			x				Flood hazard perception in Paulins Kill Valley, Warren Co.,New Jersey - Beyer
B-009	6C				x	x	x	An engineering economic study of the growth potential for industrial users of Passaic River water - Lesser
B-010	5G				x	x	x	Photosynthetic reaeration in the upper Passaic River - Hunter
B-011	5G				x	x	x	Process control model for oxygen regeneration of polluted rivers - Davidson, Hunter
B-012	5C				x	x	x	Effects of thermal and other forms of pollution on some anadromous fishes - Westman
B-014	4B				x	x	x	Surface and ground water potentialities, Mullica River Basin - Snow, Durand, Granstrom

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
NEW JERSEY (continued)								
B-017	6B					x	x	An engineering-economic study of the industrial growth potential for the upper Passaic River Basin - Lesser, Spinner
B-018	6D						x	Surface and ground water potentialities of the Mullica River Basin, Phase II - Granstrom, Durand
B-019	5G						x	Process control model for oxygen regeneration of polluted rivers, Phase II - Davidson
B-022	5B						x	A study of the factors determining the oxygen uptake of benthall stream deposits - Hunter
B-024	1A						x	Artificial mixing of density stratified fluids, Phase II - Brush
NEW MEXICO								
A-001	2A	x	x	x				Synthetic hydrology - Hernandez
A-002	5A	x	x	x				Gas chromatographic evaluation of bacterial stream pollution - Garner
A-003	5C	x	x	x	x			A study of the effects of water quality and environmental factors affecting fresh water vertebrates - Whitford
A-004	2G	x	x	x	x			The effects of soil properties on the retention, percolation and run-off of precipitation - Anderson
A-005	3C	x	x	x				Plant composition and soil properties as affected by irrigation water quality - Dregne
A-006	3F	x	x	x	x	x		The effect of irrigation method and moisture and fertility levels upon maximizing water use efficiency and quality cotton fiber production - Williams
A-007	6D	x	x					Inventory of irrigation areas and determination of consumptive uses by areas - Henderson
A-008	4B	x	x	x	x			Hydrogeology of the lower Rio Grande Valley and adjacent intermontane areas of New Mexico - King
A-009	6D	x	x					Economics of alternative pricing systems to allocate scarce water supplies - Long
A-010	5A	x	x	x	x			A comparison of the aquatic beetles in the five major watersheds of New Mexico with special emphasis on the family Dytiscidae - Zimmerman
A-011	5D			x				U-tube aeration - Speece
A-012	6E			x	x	x		History of water utilization in the southwest, with particular reference to New Mexico - Clark
A-013	5D				x			Nitrogen removal from natural waters - Speece
A-014	2F				x			Fluctuations in water droplet evaporation rates - Bryant

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
NEW MEXICO (continued)								
A-015	3A				x			Solar heating of water to very high temperatures - Cobble
A-016	2G					x	x	Model study to predict salt distribution and concentration of water in soil profiles - Alfaro
A-017	6A					x	x	Decision models for minimizing the cost of information or error in estimating benefit-water relationships with special applications to irrigation - d'Arge
A-018	5F					x	x	Feasibility of treating and recycling used fish hatchery water - Speece
A-019	2H					x	x	Comparative productivities of small bodies of water in desert and montane areas of southern New Mexico - Whitford
A-020	5D					x		Development of a froth process for the treatment of sour water - Wilson
A-021	5C						x	An investigation of primary productivity and an analysis of nutrients in Elephant Butte Reservoir using the 14C method - Johnson
A-022	6D						x	Applying linear programming models for estimating the agricultural demand function for water - Gisser
A-023	1B						x	An NMR and calorimetric study of the interactions between lanthanide ions and water - Birnbaum
A-024	2D						x	Cloud chamber study of water evaporation - Good
B-001	6D		x	x	x			Recreational values of water in the major reservoirs of New Mexico - Gray
B-002	6B		x					An appraisal of some of the factors adding to or detracting from the socio-economic use of New Mexico's thermal waters - Bertholf, Summers
B-003	6E		x					Reconnaissance study of the Pecos River Basin, New Mexico - Hernandez
B-005	2D			x	x			Geohydrologic factors affecting rate of evaporation from moist playas - Titus
B-006	6A			x	x			A comprehensive water resources analysis of a typical overdrawn basin and an irrigated semiarid area - Pecos River Basin, New Mexico - Stucky, Jacobs, Wollman, Hernandez
B-007	6D				x			Determination of sensitivity of U.S. water demand-supply models to specified changes in conditions - Wollman
B-008	6D				x	x	x	Irrigable acreage in New Mexico and projected demands for irrigation water - Henderson, Hanson
B-011	6A					x	x	A comprehensive water resources analysis of a typical overdrawn basin in an irrigated semi-arid area - Pecos River Basin, New Mexico - Stucky
B-012	6E					x	x	Patterns of policy making in water development - Ingram
B-013	3A					x	x	A comprehensive analysis of the Tularosa Basin saline water resources: Their availability and potential economic development - Kittlowski, Sommers, Titus

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
NEW MEXICO (continued)								
B-014	6B					x	x	Irrigability classification of New Mexico soils as a guide for water importation - Anderson
B-015	6B						x	Irrigability classification of New Mexico lands as a guide for water importation - Anderson
B-016	6B						x	An analytical interdisciplinary-evaluation of the utilization of the water resources to the Rio Grande in New Mexico - Hernandez
B-017	6D						x	Estimation of capital water elasticities of substitution in U.S. manufacturing - d'Arge, Falkson
NEW YORK								
A-001	6D	x	x	x	x	x		Water supply-demand - Allee, Falkson
A-002	6B	x	x	x				Determining optional policies for operating water resource systems - Lynn, Loucks
A-003	6E	x	x	x				Water and related land resources law and political institutions, I - Farnham
A-004	2D	x						The hydrodynamic and energy budget aspects of pan evaporation - Brutsaert
A-005	6B	x						The defense-involved company's role in expansion of non-defense government programs in water resource development, mass transportation, and urban development-Lall
A-006	8A	x						Investigation of two-phase (liquid-solid) problems - Graf
A-007	5C	x	x	x	x			Eutrophication of water resources in New York State - Barlow
A-008	2E		x	x				Great Lakes III, hydraulics of channels, conecting two reservoirs, with special attention to the problem in the Great Lakes - Graf
A-009	2H		x	x	x			Great Lakes IV, Hydrologic systems analysis of the Great Lakes - Brutsaert
A-010	6A				x			Stochastic models for river basin planning and management - Loucks
A-011	6A				x			Stochastic models for hydrology - Prabhu
A-012	5A			x	x			Oxidation characteristics of biological treatment plant effluents in natural waters - Gates
A-013	5C			x	x	x	x	Effect of water quality on first-year mortality of largemouth bass - Eipper
A-014	5D			x	x			Effect of chemical structure on biodegradability of organic molecules - Alexander
A-015	5C			x	x			Enzymatic degradation of pesticides by aquatic organisms - Young
A-016	5D				x	x	x	Design of wastewater treatment systems to satisfy effluent quality requirements based on intended use - Lawrence
A-017	5D				x			Discharge of industrial wastes to municipal sewer systems - Behn

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
NEW YORK (continued)								
A-018	2E				x			Application of aerial photographs for the investigation of the discharge properties of drainage basins - Belcher
A-019	5C				x			Investigation of phosphorus availability in oligotrophic lakes - Webster
A-020	2F				x			Study of geologic structural control on the flow and discharge of geothermal waters - Kiersch
A-021	2D					x		Three-deminsional approach to the exchange of heat and water vapor between a large water body and the atmosphere - Brutsaert
A-022	6E					x		Research on decision making and related managerial aspects of British water resources programs - Flash
A-023	6B					x	x	Conservation and development planning for the estuarine zone (a case study in the Town of Southold, Long Island) - Hamilton
A-024	6A					x	x	A case study of water resources development: An analysis of a proposed project on the Missouri River - Hamilton
A-025	5C					x	x	Eutrophication as a problem in the Finger Lakes - Oglesby
A-026	2H						x	Mineralization of organic phosphorus in oligotrophic lake sediments - Webster
A-027	6E					x		Investigation of water rights and water law and the effects of these on the development of the water resources of New York State - Farnham
B-002	6D		x	x	x	x		Impact of water based recreation - Burgess
B-003	6E		x	x	x	x		Investigation of water rights and water law and the effects of these on the development and utilization of water resources of New York - Farnham
B-005	2A			x				Mathematical models of hydrologic systems - Liggett
B-008	2A			x	x			Role of langmuir circulations in mixing of Lake George - Scott
B-011	2H				x	x	x	Basic research in the aquatic environment-effects of eutrophication on plankton algae and benthic plant communities - Mulligan
B-014	6B					x	x	Planning analysis for the non-market values of water resources with particular emphasis on recreation - Kalter
B-015	2H					x	x	Role of langmuir circulations in mixing of Lake George - Scott
B-017	6A						x	Role of public involvement in water resources planning and development - Allee
NORTH CAROLINA								
A-001	2E	x	x	x	x			Runoff from rainfall and the routing flow in streams in North Carolina - Amein
A-002	5F	x						A multi-stage research program on the relationships between aquatic algae and fungi and water quality - Bell
A-003	6G	x	x	x				Productivity studies in North Carolina salt marshes - Cooper
A-004	6E	x	x	x				A comparison of state water pollution control laws and programs - Heath

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
NORTH CAROLINA (continued)								
A-005	2K	x	x	x				Solubility equilibria involving metal oxides and corresponding aqueous metal perchiorates - Hentz
A-006	5G	x						Recoverable warp sizes: A feasibility study - Jennings
A-007	2F	x	x	x	x			Diffusion and dispersion in porous media - Kaskef
A-008	5G	x	x	x	x			The movement and storage of water in North Carolina soils and the role of soil in determining water quality - Lutz
A-009	4B	x	x	x				Ground water yields in the Raleigh quadrangle - Welby
A-010	5G	x	x	x				Effect of different low-flow hydrologic regimes on water quality management - Sherwani
A-011	6D	x	x	x				Criteria for evaluating the quality of water based recreation facilities - Scott
A-012	4B	x						Rainfall disposition over a sloping land mass - Wiser
A-014	5G		x					Current studies in the Pamlico River and estuary - Horton
A-015	5C		x					A preliminary study of bacterial heterotrophy in the Pamlico River - Hobbie
A-016	5D		x					Recovery of warp sizes, Phase II - Jennings
A-018	7C				x	x		Water resources of North Carolina: An inventory of information and data - McJunkin
A-019	6G				x			A preliminary study of the ecology, present and alternative future land use patterns in the Dismal Swamp area of North Carolina - Cooper
A-020	2L				x			Current study of the Neuse River and estuary - Woods
A-021	7A				x	x		Designing and testing a water monitoring system for pesticides in North Carolina - Sheets
A-022	5F				x			Oxygenation of iron (II) in continous reactors - O'Melia
A-023	6B				x			Lake-oriented residential subdivisions on North Carolina: Decision factors and policy implications for urban growth patterns - Weiss
A-024	6A				x			Simulation of regional economic impacts of water resources development: An exploratory study - Wallace, Naylor
A-025	5C				x			Pigment indices of environmental oxygen stress - Odum
A-026	2F				x			Computer simulation of aquifers of coastal plain of North Carolina - Sherwani
A-030	5C					x		A field and laboratory study of fluoride uptake by oysters - Hobbie
A-031	5B					x	x	Water contamination by fertilizer nitrogen and phosphorus - Lutz
A-032	5D					x		Radiation induced grafting of vinyl monomers to lignin - Brown
A-033	4B					x	x	Water table control and subsurface irrigation in mineral and high organic coastal plain soils - Kriz
A-034	5B					x	x	Quality of storm water drainage from urban land areas in North Carolina - Bryan
A-035	3E					x		Exploratory study of water use and waste control in textile industry - Rutherford
A-036	3E					x		Survey of water utilization and waste control in the pulp and paper industry - Rogers

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
NORTH CAROLINA (continued)								
A-037	3E					x		Water utilization and waste control in the poultry processing industry - Crosswhite
A-038	6B					x		Exploratory study of sociological aspects of water resources research - Davis
A-039	5A					x		Exploratory study on the application of neutron activation analysis techniques to water resources research and management - Bohannon
A-040	5B						x	Contamination of surface and ground water with insecticides and herbicides applied to cultivated crops - Sheets
A-041	5C						x	Estuarine ecosystems and high temperatures - Hobbie
A-043	2E						x	Superposition of subseasonal flows on seasonal flows in multivariate hydrologic simulation - Moreau
A-044	2L						x	Relation of estuarine algae to water quality - Bellis
B-003	5A			x	x	x		Exchange of phosphorus species between living and nonliving systems in fresh water environments - Weiss
B-004	5C			x	x	x		Changes during eutrophication of an estuary - Horton
B-005	4B					x	x	Computer simulation of aquifers of coastal plain of North Carolina - Sherwani
B-006	4B					x	x	Analog modeling to determine freshwater availability on the outer banks of North Carolina - Kriz
B-007	5G					x	x	Water quality management of impoundments - Weiss
B-010	3B					x	x	Economic evaluation of changes in land use of a municipal watershed as a guide to decision-making - Maki
B-012	6A					x	x	Multipurpose reservoirs and urban development - Weiss
B-013	6B					x	x	Development of a system of determining the capacity of water resources to support various types of combinations of recreation use - Hammon
B-020	5C						x	Nutrients and eutrophication in a North Carolina estuary - Hobbie
NORTH DAKOTA								
A-001	5D	x	x	x	x			Livestock waste disposal system involving reuse of water - Pratt
A-002	5D	x	x					Treatment of lye peel potato wastes by coagulation - Fossum
A-003	5D		x	x				Microbiology of sewage lagoons: Role of purple sulfer bacteria in stabilization of industrial waste - Vennes
A-004	5G	x	x	x				Water quality in relation to productivity of Lake Ashtabula reservoir in southeastern North Dakota - Whitman
A-005	3C	x	x	x	x			Effect of water quality and management on chemical and physical properties of selected soils under irrigation - Schroer

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970						PROJECT TITLE and PRINCIPAL INVESTIGATOR
		5	6	7	8	9	0	
NORTH DAKOTA (continued)								
A-006	5G	x	x	x				The biogeochemistry of Devils Lake, North Dakota - Noble, Owen
A-007	5C	x	x	x				Mussels and pollution in the Red River Drainage, North Dakota and Minnesota - Cvancara
A-008	2D	x	x	x	x			Determination of suitable average values of meteorological data for use in estimation of evapotranspiration - Schwendeman, Younggren
A-009	5D			x	x	x		Water balance in sewage stabilization lagoons - Fossum
A-010	5D				x	x		Secondary treatment of hog waste in an anaerobic stabilization pond - Butler, Fulghum
A-011	6G				x	x		Primary productivity, and standing crops in relation to water quality in Lake Ashtabula reservoir, North Dakota - Peterka
A-012	2J				x	x		Rainwash and soil creep in western North Dakota - Clayton
A-013	6G				x	x	x	Distribution and ecology of river mollusks in central and western North Dakota - Cvancara
A-014	6G				x	x		The limnobiochemistry of Devils Lake, North Dakota - Neel, Owen, Vennes
A-015	6G				x	x		Pond ecology and waterfowl production in relation to optimum water resources utilization in the Turtle Mountains of North Dakota - Cassel
A-016	5D				x	x		Microbiology of sewage lagoons; Effects of industrial wastes on coliform and other enteric organisms - Vennes
A-017	5C					x	x	Investigation of the importance of the food chain in the initiation and continuance of botulism intoxication among waterfowl inhabiting lakes and sloughs in the Devils Lake - Reilly
A-018	5F				x	x	x	Water quality improvement: Kinetics and mechanism of the chlorination-degradation of urea and uric acid - Rathmann, Fleetwood
A-019	2K				x	x	x	Effects of sugar refining lagoon effluents on biological, physical, and chemical properties of fargo clay - Funke
A-020	5C				x	x	x	Influence of water quality in maintaining whiteness when laundering white fabrics - Janecek
A-021	1B					x		An X-ray diffraction study of water structures and solvated ions in aqueous solutions - Bale
A-022	6G					x	x	Phytosociology of the bottomland forests of the Missouri River, North Dakota - Burgess
A-023	2F						x	The study of groundwater movement in selected areas of North Dakota - Clayton

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
NORTH DAKOTA (continued)								
A-024	5A						x	Light initiated reactions in water containing chelated metal impurities - Koob
A-025	2F						x	A study of the saline water seeps in Hettinger County, North Dakota - Laird
A-026	6G						x	The limnobiology of the Devils Lake Chain, North Dakota - Neel
A-027	6G						x	Environmental factors influencing egg survival of the Walleye and Northern Pike in Lake Ashtabula Reservoir, North Dakota - Peterka
A-028	6G						x	Pond ecology, waterfowl populations and production and water resources utilization in the Turtle Mountains of North Dakota and Manitoba - Cassel
B-001	5G		x	x	x	x		A limnological study of Spiritwood Lake, North Dakota - Comita
B-002	8B	x	x	x	x	x	x	Economic impacts of water resource development - Hertsgaard
B-003	6B			x	x	x		Effects of irrigation development on trade patterns and income generation - Hertsgaard
B-004	4B			x	x			Effects of groundwater seepage on stream regimen - Clayton
B-007	6A				x	x		A physical and economic analysis of alternative irrigation methods in a subhumid climate - Stegman
B-008	4B				x			Use of gravity shafts for ground water recharge, Phase I - Skodje, Stegman
OHIO								
A-001	5G	x	x	x				Development of a "natural" laboratory for study of acid mine drainage - Smith
A-002	5G	x	x	x				A study of the microbial flora of acid waters - Dugan
A-003	5G	x	x	x				Development of biological indices to pollution levels in streams affected by acid mine and oil field brine wastes - Dambach
A-004	5B	x	x	x				A study of groundwater contamination due to saline waste water disposal in Morrow County oil fields - Lehr
A-005	6B		x	x				Alternative economic responses to the acid mine drainage problem in southeastern Ohio - Tybout
A-006	5C				x	x	x	Influence of suspended microscopic substances on the metabolic activities of microorganisms responsible for biological enrichment of water - Pfister
A-007	5C				x	x	x	Cladophora as related to pollution in western Lake Erie - Taft
A-008	5B				x	x		Relationships between phosphate and other chemicals at the water substrate interface in western Lake Erie - Britt
A-009	6B				x	x	x	Public investment criteria for water-oriented recreation in the Lake Erie Basin - Tybout

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
OHIO (continued)								
A-010	6B				x			Pollution taxes and the costs of water quality management - Boyd
A-011	5D				x	x	x	Precipitation of phosphates from water with ferrous salts - Svanks
A-012	2F				x			Ground water basin dynamics - Preul, Laushey
A-013	5D					x	x	Removal of trace metals from water by ion flotation - Rubin
A-014	5D					x	x	Relationship of activated sludge bulking in organic loading, oxygen availability and hydraulic characteristics of the aeration tank - Shumate
A-015	2F					x		Flow analysis of hydraulic connectors in artificial recharge systems - Pettyjohn
A-016	5D						x	Coagulation of clays with hydrolizing metals - Rubin
A-017	5C						x	The origin and development of Microcystis, Anabaena, and Aphanizomenon blooms in western Lake Erie - Taft
A-018	5B						x	Chemical and sediment movement from agricultural land into Lake Erie - Schwab
B-002	5C		x	x	x	x	x	Strip mining and water quality - Vimmerstedt, Struther, Finney
B-004	5G		x	x				Strontium isotope composition and trace element concentration in Lake Huron and its principal tributaries - Faure
B-005	4A		x	x	x	x	x	Hydrologic investigation of small watersheds in Ohio - Taiganides
B-006	2F			x	x	x	x	Well drawdown in unconfined aquifers under non-steady conditions - Taylor
B-008	5C				x	x	x	Study of biological systems in the Scioto River as indices to water quality - Olive
B-012	6B				x	x	x	Community reactions to water resource problems in relation to planning - Dynes
B-013	5C				x	x	x	The ecologic impact of the interactions among microorganisms and aquatic contaminants in Lake Erie - Pfister
B-017	6A					x	x	A systems analysis of the western basin of Lake Erie - Hanna, Tybout
B-018	5C						x	The ecologic impact of the interactions among microorganisms and aquatic contaminants in Lake Erie, Phase II - Pfister
B-019	2A						x	Hydrologic investigations of small watersheds in Ohio, Phase II - Taiganides
B-022	6B						x	Community reactions to collective stress: Its implications for water resource planning, Phase II - Dynes, Quarantelli
B-023	6A						x	A systems analysis of the western basin of Lake Erie, Phase II - Randles, Tybout
OKLAHOMA								
A-001	6G	x	x	x	x			Biological factors affecting turbidity and productivity in prairie ponds in the southern Great Plains - Toetz
A-002	5C	x	x	x	x			Chemical and thermal characteristics of Keystone Reservoir - Dorris

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970						PROJECT TITLE and PRINCIPAL INVESTIGATOR
		5	6	7	8	9	0	
OKLAHOMA (continued)								
A-003	5F	x	x	x	x			Development of design criteria for individual domestic water supplies from surface impoundments - Daniel
A-004	3F	x	x	x	x			Reduction of water application losses through improved distribution channel designs - Garton
A-005	4A	x	x	x	x			Water yield as influenced by watershed characteristics and small upstream reservoirs - Garton
A-006	2E	x	x	x	x			The mechanism of direct surface runoff from rainfall - Garton
A-007	5D	x	x					Enzymes and catalysts for purification of industrial waste water - Fulton
A-008	5G	x	x	x	x			Oxygen diffusion in semiquiescent waters - Gaudy
A-009	1B	x	x	x	x			Thermodynamic properties of brine - Rowe
A-010	5D			x	x	x		An evaluation of recent approaches for the design of biological wastes treatment - Graves
A-011	5G			x	x	x		Nutritional pollution - Reid
A-012	2H				x	x	x	Biological fixation and transformation of nitrogen in small impoundments - Toetz
A-013	5G				x	x	x	Behavior of water in a southwest impoundment - Lake Thunderbird - Klehr
A-014	3F					x	x	Increasing water supplies by suppression of reservoir evaporation - Crow
A-015	3F					x	x	The hydraulics of spatially varied steady flow in an irrigation distribution channel with furrow outlets - Garton
A-016	2A					x		Overland flow analysis for a simulated vegetated surface - Rice
A-017	5D					x	x	Operational stability of the extended aeration process - Gaudy
A-018	5C					x	x	Comparison of energy flow parameters of midge populations in biological oxidation ponds - Wilhm
A-019	1B					x	x	Measurement of thermodynamic properties of saline solutions - Rowe
A-020	6B					x		A preliminary analysis of the impact of the Arkansas Waterway on land tenure and value in Oklahoma - Warner
A-021	8A						x	Reuse of surface runoff from furrow irrigation - Barefoot
A-022	6A						x	Allocation of water resources projects methodology - Reid
B-004	5G		x	x				Critical review of the Oklahoma State water resources quality criteria - Reid
B-005	5B	x	x					Carbon sources in algal populations and algal community structure - Dorris
B-006	6D			x	x	x		Water resources planning studies: Oklahoma and Arkansas - Gaudy
B-008	5C				x			Carbon sources and algal community structure and metabolism in a reservoir undergoing eutrophication by domestic and industrial effluents - Dorris
B-010	6D				x	x	x	Economic efficiency in the allocation of irrigation water over time - Eidman

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
OKLAHOMA (continued)								
B-012	3F					x	x	Plant population effects on the efficient use of water - Stone
B-013	5A						x	The identification and measurement of chlorinated hydrocarbon pesticides accumulated from urban runoff - Klehr, Engleken
OREGON								
A-001	4C	x	x	x	x	x	x	Hydrology of water yield prediction - Krygier, Klingeman
A-002	6E	x	x	x	x	x	x	Appraisal of water management institutions - Clark
A-003	2H				x	x	x	Classification of the lakes of the State of Oregon - Donaldson
A-004	4D				x			A survey of water induced hazards of the Portland area - Palmer
B-001	2G		x	x	x	x	x	Prediction of unsaturated flow rates from physical properties of porous medium - Boersma
B-004	5C			x	x	x		Effects of pulp mill effluents on the growth and production of fish - Warren
B-009	3C					x	x	Use of reactor cooling water from nuclear power plants for irrigation of agricultural crops - Boersma
B-011	6B					x	x	Socio-cultural impacts of water resource development in the santiam - Hogg
B-012	5C					x	x	Temperature requirements of salmonids in relation to their feeding, bioenergetics, growth, and behavior - Davis
B-013	5C						x	Effects of pulp and paper mill effluents on growth and production of fish, Phase II-Warren
B-016	6B						x	Decision making in water resource allocation: A case study of social, economic and legal considerations - Brown
PENNSYLVANIA								
A-001	5D	x		x				Sewage oxidation rates in neutralized acid mine water streams - Kountz
A-002	5F	x	x	x	x	x		Crushed limestone barriers for neutralization of acid streams - Kountz
A-003	5C	x	x	x	x	x		The effects of nutrient additions and stream dynamics on stream eutrophication - McDonnell
A-004	5D	x	x					Removal of both metal and detergent contaminants in streams by foam fractionation - McLean
A-005	4C	x	x	x	x	x	x	The carbonate hydrogeologic environment, its relationship to land use, water resource development and management - Parizek

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		5	6	7	8	9	0	
PENNSYLVANIA (continued)								
A-006	3B	x	x	x	x	x	x	Characteristics of streamflow of small watersheds in Pennsylvania and factors that influence it - Sopper
A-007	6D	x	x	x	x			An economic analysis of water utilization in Pennsylvania - Jansma
A-008	5B	x	x					An evaluation of the significances of Escherichia in sewage effluent and water supplies - Glantz
A-009	6B		x	x	x	x		A water supply demand analysis in Clinton County, Pennsylvania, study in economic hydrology, Phase I and II - Raphael
A-010	5B			x	x			Tracing pollution in water by means of Escherichia coli serotypes - Glantz
A-011	5G			x				Foam fractionation of mixed streams of acid mine water and sewage effluent - McLean
A-012	7B		x	x	x	x		Hydrologic significance of chemically derived mean basin temperatures - Lee
A-013	2F				x	x	x	Numerical simulation of groundwater flow systems (Phase I) - Donohue
A-014	6B					x	x	Criteria for determining economic priorities in awarding sewage facility construction grants - Jansma
A-015	2B					x		Time distribution of rainfall intensities - Hiemstra
A-016	2E					x		Anomalous flood response in regions of similar geomorphic characteristics - Reich
A-017	6B					x	x	Sociological impact of a flood control reservoir - Phase I: Influential's perception and social organization. Phase II: Household adjustment to water-based employment and recreation - Leadley
A-018	5D					x	x	Microbiological characterization of activated sludge in a wastewater treatment plant chemically modified for phosphorous removal - Unz
A-019	1B					x		Application of laser ionization mass spectrometry to the identification of organic salts in polluted water - Vastola
A-020	5C						x	Detection of nutrient limitations of algal growth in surface waters - McDonnell
A-021	5A						x	Escherichia coli serotypes in microbial pollution of water - Glantz
B-001	5C		x	x				Renovation of waste water through application to agricultural cropland and forest land - Kardos, Meyers, Sopper
B-003	5F		x					Thermodynamics of reactions in acid mine drainage - Barnes, Romberger
B-004	5G			x				Treatment of coal mine drainage waters with coal products - Lavell
B-008	5G			x				Removal of phosphate from water by aluminum and iron - Hsu
B-010	4C			x				Simplification of integrated storm water planning for modern multiple land use in urban and suburban developments - Reich
B-012	6B				x	x		Influence of water quality on the recreational use and income of streams - Gamble
B-016	2I				x	x		Respiration of aquatic macrophytes in eutrophic systems - McDonnell
B-020	5E					x	x	Effects of irrigation of municipal sewage effluent on spoils banks - Sopper

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
PENNSYLVANIA (continued)								
B-024	3D						x	Residential water usage change potential related to attitudes toward water and knowledge of usage behavior - Carson
B-025	6B						x	Environmental quality perception of water based recreation areas - Gamble
B-026	5C						x	Respiration of aquatic macrophytes in eutrophic systems, Phase II: Applications to stream analysis - McDonnell
B-028	2A						x	Watershed behavior under controlled simulated rainfall - Sopper
PUERTO RICO								
A-001	5A	x	x	x	x			Determination of present levels of pollution in some Puerto Rico bays - Santiago-Vazquez
A-003	6D	x	x	x	x	x	x	Quantitative analysis of water use patterns in Puerto Rico - Vazquez
A-004	4B	x	x					Development of ground water control methods for the heavy soils of Lajas Valley - Vazquez
A-005	3F	x	x	x	x			Water requirements of sugarcane under irrigation - Vazquez
A-007	5G		x	x				A study of self-purification rates of polluted streams in Puerto Rico - Candelario
A-008	3D		x	x				Determination of domestic water consumption rates under varying water pressures - Nunez
A-009	6B			x	x			Study of the relevance of selected ecological factors related to water resources and the social organization of fisherman villages in Puerto Rico - Blay
A-010	6A				x	x		Management and control of water in Puerto Rico - Cordero
A-011	2E				x	x		Loss coefficient in a channel bend with naturally deformed bed - Yen
A-012	7C				x	x		The water resources situation in Puerto Rico: An evaluation of published information - Quijano
A-013	4C				x	x		Human factors involved in the development of a watershed project in Yabucoa, Puerto Rico - Del Rio
A-014	8A				x	x	x	Theoretical and experimental study of supercritical flow in circular drains and of the formation of hydraulic jump in the same - Nunez
A-015	6D					x	x	The demand for water based recreation in southwest Puerto Rico - Ramgolam
A-016	5C				x	x	x	Comparative study of the benthic Microbial biota in some coastal areas of Puerto Rico - Angel
A-017	6B				x	x	x	The impact of water resources on the industrial and economic development of south Puerto Rico - Pascua
A-018	6G					x	x	Socio-economic factors related to the incidence of a water borne disease - Uzdavini

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PUERTO RICO (continued)								
A-019	8A					x	x	Analysis of a pipe when in contact with the ocean bottom and rigidly fixed at one end - Georas
A-020	2A					x	x	Hydrologic study of the Yaguez River watershed - de Vera
A-021	5B					x		Movement of non-conservative pollutants by waves and currents in protected waters-Kamel
A-022	6D					x	x	The determination of the significance of the variables affecting residential water consumption - Kattan
A-023	5A					x	x	Determination of the rate of biodegradation in some polluted tropical waters and in some types of liquid wastes common in Puerto Rico - del Valle
A-024	6B						x	Study on the costs and effects of irrigation in the planning and implementation of the Lajas Valley agricultural development program - Cordero
RHODE ISLAND								
A-001	3F	x	x	x				Water loss through interception by mixed oak forest - Brown
A-002	5A	x	x					Structural chemistry of yellow organic matter in fresh water - Felbeck
A-003	5B	x	x	x				Movement of manganese into ground water supplies - Deluise
A-004	5B	x	x					Analysis of the effluent from a nuclear fuel recovery plant - Blecharczyk
A-005	6B	x						Impact and incidence of taxation on water utilities in Rhode Island - Pitterman
A-006	8B	x	x	x				Static and hynamic behavior of soils - Nacci
A-007	5G	x	x	x				Effects of obstructions on aeration of flowing streams - Hagist
A-008	2F	x	x	x				Ground water characteristics by resistivity criteria - Fisher
A-009	3F	x	x	x				Water economy of turf grass - Stuckey
A-010	6D		x	x				Variations in water consumption based on economic and social characteristics of the household - Spaulding
A-011	5A		x	x				Analysis of natural radioelements in raw water - Rose
A-012	3A		x	x	x			Scale reduction in desalination by calcium sulfate solubility inversion - Thompson
A-013	5C		x	x	x			An investigation of the interrelationship of organic matter and trace elements - Corless
A-014	5D		x	x	x			Development of methods for controlling the copper content in water - Mairs
A-015	5D		x	x	x			Oxygen transfer in aeration process - Poon
A-016	8B				x	x		Dynamic behavior of soils - Nacci
A-017	5F				x	x		Iron and manganese removal from small ground water supplies - Deluise
A-018	5A				x	x		Structural chemistry of yellow organic matter in fresh water - Felbeck
A-019	5A				x	x		Analysis of trace elements in water - Rose

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RHODE ISLAND (continued)								
A-020	3A				x	x		Small desalination unit to test scale reduction additives - Madsen
A-021	5C				x	x		Correlation of structure vs. activity of pollutants of fresh water - Bond, Fuller
A-022	5C				x	x		The insect order Plecoptera as a biological index of fresh water quality in Rhode Island - Kerr
A-023	8B				x	x		Investigation of soil freezing - Roderick
A-024	5D					x	x	Flocculation of colloids with polyelectrolytes - Sussman
A-025	5A					x	x	The gauze pad method for the isolation of viruses from inland and estuarine waters - Miller
A-027	5A					x		The bioassay of water pollutants with cultured mammalian cells - Fisher
A-028	5C						x	Correlation of structure vs. activity of pollutants of fresh water - Bond
A-029	5F						x	Cartridge filtration for iron and manganese removal - DeLuise
A-030	5A						x	The bioassay of water pollutants with cultured mammalian cells: Part II - Fisher
A-031	5B						x	Criteria for recognition of estuarine water pollution by aerial remote sensing - Fisher
A-032	6E						x	Some legal, social and economic problems of groundwater pollution - Burke
A-033	5D						x	Control of geotrichum candidum in biological waste treatment - Pooh
A-034	2K						x	Binding and precipitation of trace elements by humic substances in natural waters - Sieburth
B-001	5A			x				Structural chemistry of yellow organic matter in fresh water (Phase II) - Felbeck
B-003	5A			x	x			Role of nematodes and related meiofauna affection fresh water quality in Rhode Island - Stessel
B-006	5G				x	x		Bouyancy and sinking characteristics of freshwater phytoplankton - Smayda
B-020	5B					x	x	Biochemical oxidation of hydrocarbons in natural waters - Houston
B-022	6G						x	Potential benefits of integrating a new community and a power reactor with special reference to the water ecology - Hammerschlag
SOUTH CAROLINA								
A-001	5C	x	x	x	x			Effect of pesticides on the ecology of fresh water organisms - Reed
A-002	6B	x	x	x	x			Study of relationships between water pollution and industrial development in South Carolina - Stepp
A-003	3F	x	x	x	x			Hydrology of the root zone - Lambert, Ligon

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SOUTH CAROLINA (continued)								
A-004	4D	x	x	x	x			Bedrock influence on sediment load of selected Hartwell Reservoir tributaries - Brown, Birkhead
A-005	2A	x	x	x	x			Temperature study of the surface water: Ground water relationship - Law
A-006	3F	x	x	x	x			Relation of soil properties to the evaporation of water from soils - Peele
A-007	5C	x	x	x	x			Water quality and waste assimilation capacity studies of an impoundment of recent origin - Wallace, Abernathy
A-008	6C			x				The use of taxes to effect an improved allocation of water resources; a case study, the textile industry - Macaulay
A-009	1B				x	x	x	Effect of drag reducing additives in water transportation - Castro
A-010	2A				x	x		Development and evaluation of hydrologic simulation models - Ligon, Law
A-011	2F				x	x		Feasibility study of electrical geophysical methods in the determination of subsurface hydrogeologic environments in the Piedmont Area of South Carolina - Drake
A-012	5D					x	x	The removal of impurities in trickling filter effluents - McLellon
A-013	5B					x		Interaction of pesticide pollutants and aquatic foodchain organisms - Reed
A-014	2G					x	x	Deep seepage on Piedmont watersheds - Ligon
A-015	2D					x	x	Evaporation and evapotranspiration in relation to soil properties and moisture stress - Peele
A-016	5C					x	x	Reservoir water quality prediction based on limnological parameters - Abernathy
A-017	6C					x	x	Study of costs of treating textile wastes in municipal and industrial sewage plants - Stipp
A-018	6A						x	Stochastic models for reservoirs - Prochaska
A-019	5D						x	The vortex chamber as a grit removal device for water treatment - Zielinski
A-020	6G						x	Biology, distribution, importance and control of deer flies and horse flies (Diptera: Tabanidae) in water oriented recreational areas - Adkins
B-001	3F		x	x	x	x		Physical, meteorological, and hydrologic aspects of evapotranspiration - Lambert
B-003	6E				x	x	x	Legal aspects of water use and control in South Carolina - Randall
B-004	6C				x	x		Use of taxes, subsidies, and regulations to control the effluent of the textile industry - Macaulay
B-006	8A				x	x	x	Computer models for water distribution systems - Wolla
B-008	2G					x	x	The interflow process on sloping watershed areas - Wilson
B-012	6B						x	Economic evaluation of zoning alternatives in the management of estuarine resources- Hite, Stepp

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SOUTH CAROLINA (continued)								
B-017	6A						x	Use of advanced water resources planning techniques in the development of regional water management programs - Dysart
SOUTH DAKOTA								
A-001	6B		x	x	x			Economic potentials for water resources development of South Dakota - Helfinstine
A-002	5G	x	x	x				Water quality and primary production of South Dakota Lakes - Schoenthal
A-003	5B	x	x	x	x			Investigation of the influence of waste disposal practices on ground water qualities - Anderson
A-004	4B		x					Determination of porosity and permeability of selected sandstone aquifers - Gries
A-005	3F	x	x	x	x			Correlating soil moisture conditions and microclimate with evaporation losses and water requirements of plants - Horton
A-006	3F	x	x	x	x			Influence of low rates of water application by sprinklers on the microclimate - Wiersma
A-007	2J	x	x	x				Apparent viscosity of fine material concentration as it affects sediment transport and velocities in open channel flow - Eno
A-009	7C	x	x	x	x			Establishment of water quality laboratory and system for storage and retrieval of information for the South Dakota State University Water Resources Research Institute - Wiersma
A-010	4B		x	x	x	x		Investigation of water losses to sinkholes in the pahasapa limestone and the relation to resurgent springs, Black Hills, South Dakota - Gries
A-011	3C			x	x	x		Effects of marginal quality irrigation water on the accumulation of salts and alkali in South Dakota soils - Lembke
A-012	8A			x	x	x		Hydrology of small drainage basins for developing hydraulic design - Lytle
A-013	8A		x	x	x			Investigation of the water retention characteristics of soils used for construction of waste water stabilization ponds - Matthew
A-014	6A				x	x	x	The modification of a predictive river basin model - Covert
A-015	5C				x	x	x	Effects of the chlorinated hydrocarbons, aldrin and dieldrin, on freshwater seed shrimp (Ostracoda) - Schmulbach
A-016	5B					x	x	Ground water contamination resulting from waste disposal - Anderson, Dornbush
A-017	3F					x	x	Evaluation and functional operation of irrigation systems - Brosz
A-018	2I					x	x	Understanding and improving the soil-plant environment for more efficient utilization of water - Horton

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
SOUTH DAKOTA (continued)								
A-019	5A					x	x	Bacteriological water quality analyses of methods for detecting fecal pollution - Middaugh
A-020	3C						x	Significance of rainfall in salt and sodium accumulations under irrigation - Madden
A-021	2F						x	Origin of the large resurgent springs in the Black Hills, South Dakota - Gries
A-022	2H						x	A geologic study of the chemical quality of Medicine Lake, South Dakota - Tipton
A-023	2E						x	Investigation of time parameter of watersheds in South Dakota - Chu
A-024	7B						x	Parameter selections in telemetry systems for irrigation - Kurtenbach
A-025	5B					x	x	Pollution potential of runoff from livestock feeding operations - Dornbush
B-002	5B				x	x	x	Chemical, physical, and biological dynamics of northern prairie lakes - Nickum
B-004	4A				x	x	x	Salinity above a water table as affected by rainfall and irrigation - Lembke
B-005	6B				x	x	x	Impact of imposing a water quality standard on a live stream - Dornbush
B-008	2J					x	x	Scour and fill in the Missouri River as related to the water resources planning - Chang
B-009	6B					x	x	Economic analysis of irrigation systems applicable to the northern Great Plains - Rose
B-013	6G						x	Effect of dredging on the nutrient levels and biological populations of a lake - Brashier
TENNESSEE								
A-001	2E	x	x	x	x			Fundamentals of turbulent mixing - Peebles
A-002	3B	x	x	x				Factors affecting water yields from small watersheds in Tennessee - Shelton
A-003	8A	x	x	x	x			Small reservoir sealing - Sewell
A-004	5D	x	x	x	x			An investigation of surfactant removal - Whatley
A-005	5C	x	x	x	x			The effects of polluting agents on the survival of indicator organisms - Womack
A-006	5G	x	x	x	x			An investigation of the effect of controlled releases on the physical chemical and bacteriological characteristics of Fort Loudoun Reservoir - Larson
A-008	5C				x			The productivity of lake polluted by organic wastes derived primarily from septic tanks - Bunting
A-009	6A				x			The determination of research needs in water resource economics, the University of Tennessee - Garrison

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970						PROJECT TITLE and PRINCIPAL INVESTIGATOR
		5	6	7	8	9	0	
TENNESSEE (continued)								
A-010	5C					x		Seasonal and diurnal aspects of zooplankton microdistribution and vertical migration - Bunting
A-011	2A					x		Geochemistry and hydrology of a small basin in the upper Buffalo River watershed, Tennessee - Stearns
A-012	1B					x	x	Isotope effect on the thermodynamic activity of water - Hook
A-013	5G					x	x	Changes in water quality parameters of reservoirs during regulated flow conditions - Larson
A-014	5B					x	x	Survival of indicator organisms and enteric bacteria in water - Womack
A-015	6B					x	x	Effect of water resources on economic growth in the Tennessee Valley region - Garrison
A-016	2E					x		Turbulent mixing in submerged two-dimensional wall jets - Remenyik
A-017	7C						x	Drouth probabilities in Tennessee - Parks
A-018	5F						x	Virus removal-water and wastewater - Drewry
A-019	2A						x	Geochemistry and geohydrology of a small basin in the upper Buffalo River watershed, Tennessee - Stearns
B-004	5C				x	x		Effect of industrial wastes of Memphis and Shelby County on primary planktonic producers - Doody
B-005	2E					x		Experimental investigation of hydraulic transients in river-reservoir systems - Tschantz
B-007	2E					x	x	Turbulent mixing in submerged two-dimensional wall jets, Phase II - Remenyik, Chu
B-010	2E						x	Experimental investigation of hydraulic transients and thermal waste dispersion in river reservoir systems - Tschantz, Miller, de Jong
TEXAS								
A-001	6D	x	x					Future agricultural water requirements - Smerdon
A-002	2A	x	x	x	x			Morphology of precipitation and runoff - Clark
A-003	5G	x	x	x	x			Influence of fatty alcohols and acids on clarity and biota of impounded water - Davis, Reynolds
A-004	6A	x	x	x	x			Development of optimization systems analysis techniques for Texas water resources - Hann
A-005	7A	x	x	x				Status evaluation of surface waters in Texas - Clark
A-006	2D		x	x	x	x		Water transfer from soil to the atmosphere as related to climate and soil properties - Runkles, Wendt

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
TEXAS (continued)								
A-007	6G		x	x	x	x		A study of selected chemical and biological conditions of the Lower Trinity River and the Upper Trinity Bay - Baldauf
A-008	2A				x	x	x	Investigation of a linear model to describe the hydrologic phenomenon of drainage basins - Schmer
A-009	5F				x	x	x	Electrophoretic clarification of water - Hiler
A-010	2A					x	x	A hydrometeorological study related to the distribution of precipitation and run-off over small drainage basins - urban vs. rural areas - Clark
A-011	6A					x	x	Water resource system optimization by geometric programming - Meier
A-012	5G					x	x	Intermediate products in the bacterial decomposition of hexadecanol and octadecanol-Langley
A-013	3F					x	x	Water use effeciency in plant growth and ambient carbon dioxide level - van Bavel
A-014	5B						x	Mathematical models of water quality parameters for rivers and estuaries - Irvine
B-001	6B		x	x				Economic impact of water impoundment: A comparative projection model - Pearson
B-002	2D				x	x	x	Study of the mechanisms and suppression of evaporation of water from soils - Runkles
B-003	6E			x	x			Condemnation of water rights - Johnson
B-004	3B				x	x	x	Mineralogy and chemistry of soils and sediments - Allen
B-005	6B			x	x	x		Evaluation of resources use and economic effects due to irrigation water availability in Texas - Schmer
B-007	5G			x	x	x		Alternate methods of mosquito control to reduce chemical pollution of waters - Huddleston, Ward
B-010	6G				x	x	x	Study of the ecology of the Navasota River, Texas - Clark
B-015	2A			x	x	x		Mathematical simulation of rainfall runoff processes - Moore
B-016	4B			x	x			Development of systems for ground water recharge into the Ogallala formation - Wheaton, Schwiesow
B-019	6B				x	x	x	Economic impact of water impoundment: Validity testing of a comparative projection model - Pearson
B-020	6G				x	x	x	Limnological investigations of Texas impoundments for water quality management purposes - Fruh, Davis
B-021	4B				x	x	x	Effect of unlined treated sewage storage ponds to water quality in the Ogallala formation - Wells
B-023	2L				x	x	x	Relation of pass openings of physical exchange and salinity in estuaries - Masch
B-024	6A				x	x	x	Application of specilized optimization techniques in water quantity and quality management with respect to planning for the Trinity River Basin - Meier

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
TEXAS (continued)								
B-025	6E				x	x	x	Institutional factors influencing water development in Texas - Trock
B-033	3F				x	x	x	Influence of transpiration suppressants, Sprinkler irrigation and moisture levels on transpiration and evapotranspiration - Gerard
B-040	5G					x	x	Selective withdrawal at Lake Livingston - Fruh
B-041	4B					x	x	Development of systems for ground water recharge into the Ogallala formation - Dvorecek, Wheaton
B-044	5G					x	x	Physiochemical responses of rivers to natural and manmade environmental changes - Gloyna
B-045	4C					x	x	A model relating water quality, vegetational structure, and urbanization in the San Jacinto River Basin - Jameson
B-059	6A						x	Development of a dynamic water management methodology - Meier, Wortham, Self
B-064	5B						x	Variation of urban runoff quality with duration and intensity of storms - Wells
B-071	3B						x	An investigation of hydrological aspects of water harvesting - Wilke, Wendt, Newman
UTAH								
A-001	6E	x	x	x	x	x	x	Cultural, social organizational, and social psychological factors associated with proposed changes in water use patterns - Andrews
A-002	7B	x	x	x	x	x	x	Instrumentation and development of techniques to measure and evaluate meteorological problems important to hydrology - Chadwick
A-003	5G	x	x	x	x	x	x	A study of the physical, chemical and biological nature of water quality factors under Utah conditions - Neuhold
A-004	7B	x	x	x	x	x		Evaluation of remote electro-magnetic sensors for detecting transpirational water use by plants subjected to various foliar chemical treatments designed to reduce transpirational losses - Schultz, Haws
A-006	5D						x	Thermodynamics of waste stabilization ponds - Hendricks
A-007	5B						x	Contributions on vegetation and substrate to water quality in wildland watersheds - Hart
A-008	8A						x	Optimum design of waste stabilization ponds - Watters
B-001	4A		x	x	x			Hydrologic atlas of Utah - Bagley
B-003	6B		x	x				Secondary economic impact from water resources development - Whatley
B-004	6B		x	x	x	x		Economic aspects of water allocation among alternative industrial - non-agricultural uses - Harline

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
UTAH (continued)								
B-005	6A		x					Application of electronic analog device to solution of hydrologic and river basin planning problems, Phase I - Bagley, Chadwick
B-006	8A	x	x	x				Design and calibration of submerged open channel flow measurement structures - Skogerboe
B-008	6B		x	x				Recreation value of water in mutually exclusive setting - Whaley
B-009	6B		x	x	x	x		The value of water in complementary industry complexes - Gardner, Wennergren
B-010	5C				x	x	x	Eutrophication of sheltered bays in a large lake - Helm
B-011	6A			x				Application of electronic analog device to solution of hydrologic and river-basin planning problems - Phase II - Bagley
B-012	4A				x	x		Analysis of small water management structures - Skogerboe, Hansen
B-013	6A			x	x			Optimizing conjunctive use of surface and groundwater - Clyde
B-015	6B				x	x	x	Recreation value of water for the production of waterfowl - Winnergren
B-016	4C				x			Application of an electronic analog computer to the evaluation of the effects of urbanization on the runoff characteristics of small watersheds - Riley
B-017	6B				x	x		Application of an electronic analog computer to the simulation of the total hydrologic-economic flow system - Riley, Chadwich, Wennergren
B-018	8A					x	x	Subcritical flow at open channel structures - Skogerboe, Austin
B-025	4C					x	x	Computer simulation of urban hydrologic systems - Riley, Chadwick
B-027	6A					x	x	Application of operations research techniques for allocation of Colorado River waters in Utah - Clyde
B-028	6A					x	x	The development of a simulation model for the Bear River Basin - Riley
B-033	2F						x	The detection of magnetic fields caused by groundwater - Chadwich
B-037	6E						x	A study of water institutions and their affect on planningand management functions-Haws
B-038	6A						x	Hybrid computer simulation as applied to the management of water salinity within a hydrologic system - Riley
VERMONT								
A-001	5G	x	x	x	x	x	x	Limnology of Lake Champlain - Potash
A-002	3B	x	x	x	x			Role of basin physiography on the runoff of small watersheds - Ragan
A-003	5G	x	x	x	x	x	x	Bottom sediments of Lake Champlain - Hunt
A-004	5A		x	x	x			Physiology and ecology of nematode fauna of Lake Champlain - Fisher

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
VERMONT (continued)								
A-005	6G			x	x			Influence of parasitism of the desmid phytoplankton of Lake Champlain - Cook
A-006	2A			x	x	x	x	Glacial geology of the Champlain Valley - Wagner
A-007	2K				x	x		Chemical characteristics of precipitation in Champlain Valley - Henson
A-008	2B				x	x		Parameterization of the observed hydrograph as a means of understanding runoff phenomena from small watersheds - Downer
A-009	2H					x	x	Autecological studies on the dominant phytoplankton species of Lake Champlain - Cook
A-011	6G						x	An experimental analysis of cyclomorphosis in Lake Champlain Daphnia - Davison
A-012	2H						x	The hydrology of the Lake Champlain Basin, Part I, Lake Champlain water levels - Downer
VIRGINIA								
A-001	5D	x	x	x				Concentration of phosphate sludges - Parsons
A-002	1B	x	x	x	x			Multicomponent mass transport in aqueous and membrane systems - Wills
A-004	3B	x	x	x	x			Evaluation of geohydrologic factors in estimation of runoff coefficients in watershed embracing multiple geologic terrane - Cooper
A-005	5B	x	x	x				Evaluation of the effect of trace elements on the activity of microorganisms - Benoit
A-006	6B		x	x				Flood damage abatement study for Virginia - Walker
A-007	6B		x	x				Queueing model for pollution transport in streams - McJunkin
A-008	6E		x					Study of water resources laws for Virginia - Walker
A-009	4A		x	x	x			Relation of selected engineering land treatments to soil water storage and rainfall use efficiency of crops - Lillard
A-010	5C	x	x	x				Water quality in relation to aquatic plants and their control - Evrard
A-011	6B			x	x			Prediction models for investment in urban drainage systems - Knapp
A-012	6G			x	x			Effect of pumped-storage reservoir operation on biological productivity and water quality - Neff
A-013	2A			x	x			Analysis of hydrologic systems - Wiggert
A-014	2A			x				Instantaneous unit hydrograph response by harmonic analysis - Wiggert
A-015	5D				x	x	x	Removal of trace organics from water by adsorption on coal - King
A-016	6B				x			Demand for water recreation - Brown, Darnton
A-017	5D				x	x	x	Treatment of dyeing bath waste streams by foaming and flotation techniques - Michelsen

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970 5	6	7	8	9	0	PROJECT TITLE and PRINCIPAL INVESTIGATOR
VIRGINIA (continued)								
A-018	2A				x	x	x	Simulation of the hydrologic cycle on small agricultural watersheds by digital techniques - Shanholtz
A-019	2D				x	x		Solar reflectance of monolayer-covered water surfaces as related to evaporation suppression - Beard, Gainer
A-020	6G				x			A preliminary ecological study of water resources and land use patterns of the Dismal Swamp area of Virginia - Wilder
A-022	2H					x		Effects of zooplankton of photosynthesis by algae in lakes - Bishop
A-023	2F					x	x	Ground water reservoir response to earth tides - Robinson
A-024	5D					x	x	Microbial releases of soluble phosphate in an activated sludge environment - Randall
A-025	5C					x	x	The effect of detergents on the oxygenation of water - Caskey
A-026	1B					x	x	Adsorption of organic compounds into solids from aqueous solutions - Wightman
A-027	5B					x		A computer program for forecasting pollution and dissolved oxygen in streams - Krutchkoff
A-028	2I					x	x	Invasion of the aquatic habitat by amphibious species of Polygonum - Mitchell
A-029	2I					x	x	Perception of water resource problems - Ibsen
A-030	5E						x	Economic disposal of waste sludges from water treatment plants - King
A-031	6G						x	A pre-impoundment ecological study of the bottom fauna and water quality in the North Anna River - Simmons
A-032	5D						x	Electrochemical activation and regeneration of carbon surfaces for tertiary water treatment - Wills
B-003	2L				x	x	x	Biological and chemical study of Virginia's estuaries - Brehmer
B-009	6B						x	Effects of reservoir operating policy on recreation benefits - King
B-017	6G						x	The effects of heated waste waters upon microbial communities - Cairns
B-021	2D						x	Convective heat transfer from water surfaces - Beard, Chen
B-025	6E						x	Analysis of water resources administrative agencies - Walker
WASHINGTON								
A-001	7B	x	x					A study of infiltration beneath a forest floor - Campbell
A-002	6E	x						Defects in the water law in the State of Washington - Johnson
A-003	6B	x	x	x	x			Simulation of a water resource system - Bevan, Paulik

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WASHINGTON (continued)								
A-004	8A	x	x	x				Fish guidance structures - Richey
A-005	6G	x	x	x	x	x	x	Some effects of water impoundments on waterfowl population and reproduction on the Snake River - Buss
A-006	3F	x	x	x	x			Drainage theory for removal of excess water from irrigated lands - Jensen
A-007	2F	x	x	x				Methods of estimating ground water recharge near the margins of plateau basalts - Crosby
A-008	5F	x	x	x	x			Evaluation of factors affecting stream self-purification - Proctor
A-009	2E		x	x	x			Determination of flows for ungaged streams - Bender
A-011	5A		x					Distribution and ecology of nematodes in irrigation water - Faulkner
A-012	6G		x	x	x			Effect of dam construction on downstream water temperatures - Nece
A-013	6D		x	x	x			The role of industrial process changes in affecting water requirements - Iulo
A-015	6D		x	x				Selection of the optimum method for estimating the demand for non-market water resources with incomplete information - Brown
A-016	5D			x	x			Improvements in treatment design for enhancing waste water quality - Carlson
A-017	6A		x	x				Computer generation of stochastic stream flow - Campbell
A-018	5C			x	x			Ecology of selected aquatic bacteria in the Snake River - Drake
A-019	5F				x	x		Enhancement of water quality using forest derived coagulating systems - Allan
A-020	2E				x	x		A study of serial correlation in annual stream runoff - Campbell
A-021	2F				x	x	x	Physical characteristics of basalt aquifers - Crosby
A-022	4C				x	x		Methods of analysis and determination of effects of alternative uses of forested lands on stream flow - Gessel
A-023	5G				x	x	x	Internal currents resulting from intermediate density inflows into stratified reservoirs - Nece
A-024	5C				x	x		Bacteriological and esthetic effects of pleasure boat waste discharge on small harbors - Seabloom
A-025	6B				x	x	x	Maximizing productivity of water used for irrigation of agricultural lands - Butcher, Whittlesey
A-026	5D					x	x	Nitrate removal from activated sludge systems - Carlson
A-027	3B					x		Effects of forest cover manipulation on water yield as studied by an electric analog - Gessel
A-028	2A					x	x	Runoff generation as a function of precipitation and watershed characteristics - Gladwell
A-029	2F					x	x	The storage coefficient as a function of water table celerity - Higgins

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WASHINGTON (continued)								
A-030	6E					x		Analysis of the Water Rights Registration Act and associated legislation of the 1967 Washington Session Laws - Johnson
A-031	6E					x	x	A comparative analysis of American and Canadian governmental arrangements for the development of regional water policy in the Columbia River Basin - Warren
A-032	2D						x	Hydrologic energy balance of stocked and non-stocked Douglas-Fir sites as calculated by meteorological methods - Fritschen
A-033	5G						x	Bioassays to determine algal growth potential of micronutrients - Funk
A-034	5G						x	Nuisance algal growth related to environmental factors - Welch
A-035	2E						x	Persistence in seasonal stream runoff - Campbell
A-036	5B						x	Controlling the location and dispersion of thermal polluting effluents - Lomax
A-037	2A						x	Quantitative assessment of disposition of precipitation in relation to streamflow - Wooldridge
B-003	5G		x	x				Estuarine water quality and fish distribution - Bevan
B-004	6G		x					Water quality as related to the survival of salmon eggs and larvae - Bevan
B-005	5A		x	x	x	x	x	Investigation of the techniques to provide advance warning of ground water pollution hazards with special reference to aquifers in glacial outwash - Crosby
B-011	5G			x	x	x		Factors affecting the movement of water and organisms within a regulated multipurpose lake - Kraft
B-018	5C			x	x	x		Ecology of nematodes in irrigation water - Faulkner
B-019	6E				x	x	x	Impact of federal water legislation at the state and local level - Hammond, Micinko
B-023	5G					x	x	Verification of models used in the management and control of water quality - Mar
B-035	6B						x	Objectives and comprehensive planning for urban storm water removal - Wooldridge
WEST VIRGINIA								
A-001	5C	x	x	x	x	x		Fish ecology and physiology in relation to acid mine drainage - Benson
A-002	5D	x	x	x	x	x	x	Acid mine drainage microbiological studies - Wilson
A-003	2A	x	x	x	x	x	x	Runoff studies on small watersheds - Burchinal
A-004	8A	x	x	x	x			Hydrologic design of small drainage structures in West Virginia - Burchinal
A-005	5C	x	x	x	x			Vascular aquatic plants related to acid mine drainage and other factors in the Monongahela River, West Virginia - Clarkson
A-006	2B	x	x	x	x	x		Influence of topographic features on rainfall in West Virginia - Dickerson

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WEST VIRGINIA (continued)								
A-007	5G	x	x	x	x			Algal relationships to recovery of acid mine streams - Bennett
A-008	5G	x	x	x	x	x	x	Geochemical behavior of iron and manganese in a reservoir (Lake Lynn, West Virginia) fed by streams containing acid mine drainage - Corbett
A-009	5G		x	x	x			Geochemical and sedimentological analysis of Tygart Reservoir - Collin
A-010	5B		x	x	x	x	x	Chemical characteristics of water in flooded bituminous coal mineshafts - Corbett
A-011	5C				x	x	x	Tolerance and cytological response of algae to mine water - Bennett
A-012	2B				x	x	x	Precipitation intensity-frequency relationships for West Virginia - Dickerson
A-013	5D				x	x	x	Phosphate uptake, storage, and release by microorganisms in wastewater treatment - Sack
A-014	5C				x	x		Effect of an acid-water environment upon the synthesis of growth factors by bacteria - Wilson
A-015	5D					x	x	Biological treatment of spent vegetable tannins - Sack
A-016	5C					x	x	Physiological effects of sublethal levels of acid water on fish - Pegg
A-017	5C					x	x	Growth of the Brown Bullhead, Ictalurus nebulosus (LeSueur), in mine acid polluted water - Benson
A-018	5C						x	Influence of acid mine water upon acid tolerance and synthetic ability of sewage Microorganisms - Wilson
A-019	2B						x	Storm characteristics and rainfall intensity in West Virginia - Dickerson
WISCONSIN								
A-001	5C	x	x	x	x			Use of lake sediment cores to estimate rate of eutrophication of lakes - Lee
A-002	5C	x	x	x	x			Biological aspects of eutrophication in Wisconsin Lakes Mendota, Crystal and Trout - Hasler
A-003	5G	x	x	x	x			Methods for harvesting or control of aquatic plants - Hasler, Cottam
A-004	2H	x	x	x	x			Circulation and mixing processes in lakes model studies - Ragotzkie
A-005	2F	x	x	x	x			Unsteady flow of groundwater and dispersion in groundwater movement - Hoopes, Monkmeyer
A-006	5D	x	x	x	x			Filtering properties of particulates in water and the filter medium as applied in water reuse systems - Polkowski
A-007	6B		x					A model to estimate the economic effects water-based recreation projects on local political sub-divisions - Lord

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970						PROJECT TITLE and PRINCIPAL INVESTIGATOR
		5	6	7	8	9	0	
WISCONSIN (continued)								
A-008	6E		x	x				Legal economic analysis of irrigation - Rose, Beuscher
A-009	6E		x	x	x			Water quality management on the Wisconsin River - Beuscher, Fox
A-011	5C			x	x			Diatom productivity in a shallow, highly eutrophic lake - Blum
A-012	5G				x			Insecticide adsorption by lake sediments as a factor controlling insecticide accumulation in lakes - Chesters, Lee
A-013	4B				x			Interrelations between the ground and artesian water resources in the glacial sediments of the Whitewater Area, Wisconsin - Byrne
A-014	5B					x	x	Eutrophic evaluation of a small multi-land use watershed - Zononi
A-015	5D					x	x	Metabolic storage of phosphorus in the activated sludge floc - Malhotra
A-017	5C					x		Nutritional ecology and community structure of the phytoplankton of Green Bay - Sager
A-018	5E					x	x	Shallow ground-water flow systems in relation to industrial and municipal water supply and waste disposal requirements - Stephenson
A-019	2J					x		Sedimentary facies in Lake Butte des Morts, Wisconsin - McKee
A-020	5G					x		Experimental reversal of the lake eutrophication process - Hasler
A-021	5C					x		Ecological studies of the surface waters of the Whitewater Creed watershed, Walworth, Rock, and Jefferson Counties - Smith
A-022	6E					x		Law affecting institutional design for water quality management - Davis
A-023	6B					x	x	Relationship of certain biological, chemical and geological parameters to the environment of the Boise Brule watershed, Wisconsin - Dickas
A-024	5C					x	x	Variability in winterkill survival in fishes from oxygen depleted waters - Magnuson
A-025	5G						x	Microfungi in the water, litter and mud of a cattail marsh bordering Lake Butte des Morts - Tews
A-026	5B						x	Multiplication of clostridium botulinum type E in the Great Lakes - Sugiyama
A-027	2H						x	Magnitude of water waves in Lake Butte des Morts and their effect on lake depth and sediment distribution - Harrison
A-028	5D						x	Applications of agglomerate size measurement to problems in water resources management - Ham
A-029	2F						x	Computer and physical models for solving subsurface problems in hydrology - Karadi
A-030	2J						x	The post-glacial history of Lake Butte des Morts, Wisconsin - McKee
A-031	6B					x		Integration of environmental and design considerations in water and related land resource planning - Lord
A-032	5C						x	Thermal effects on biological production in nutrient rich ponds - Hasler

1/ PROJ. NO.	2/ FCST CAT.	PROJECTS SUPPORTED FY-1965 - FY-1970						PROJECT TITLE and PRINCIPAL INVESTIGATOR
		5	6	7	8	9	0	
WISCONSIN (continued)								
A-033	2E						x	Application of magnetohydrodynamics to the measurement of liquid velocity and turbulence - Villemonte
B-002	6F		x	x	x	x		Physical techniques and institutional mechanisms for integrated adjustment within flood plain hazard zones - Yanggen
B-004	5B		x	x	x	x		The nitrogen cycle in surface and sub-surface waters - Witzel
B-008	5G		x	x				Insecticide adsorption by lake sediments as a factor controlling insecticide accumulation in lakes - Chester
B-009	5G			x	x	x	x	Investigations of the circulation of Lake Superior - Ragotski
B-012	2E			x	x	x		Application of magnetohydrodynamics to measurements of liquid velocity and turbulence - Villemonte
B-013	5G			x	x	x	x	Manipulation of reservoir water for improved quality and fish population response - Wirth
B-016	5G				x	x	x	Insecticide adsorption by lake sediments as a factor controlling insecticide accumulation in lakes, Phase II - Chesters
B-018	5G					x	x	Improving surface water conditions through control and disposal of aquatic vegetation - Bruhn, Livermore
B-019	5G					x	x	Changes in water environment resulting from aquatic plant control - Cottam
B-020	5A					x	x	Biological N2 fixation in lakes - Burris
B-021	2F					x	x	Unsteady flow of ground water - Monkmeyer, Hoopes
B-022	2K					x	x	Plant-available phosphorus status of lakes - Armstrong
B-024	5C						x	Biological N2 fixation in lakes, Phase II - Burris
B-028	6G						x	Ecological responses of fishes and fish food organisms to heated effluent: Case study of Lake Monona, Wisconsin - Magnuson
B-030	6E						x	Institutional design for water quality management - Fox
WYOMING								
A-001	6A	x	x	x	x	x	x	Water resources operations study - Bellamy
B-001	4C			x				The effects of varying land and water use of streamflow regimen - Rechard
B-002	6B				x	x	x	Value of the game and fish resources in relation to the future utilization of the water of the Green River drainage in Wyoming - Baxter
B-003	6D						x	Consumptive use by high mountain meadow irrigation - Rechard, Burman

APPENDIX L

TITLE II GRANTS AND CONTRACTS - 1968-1970

1/ PROJ. NO.	2/ FCST CAT.	YEARS SUPPORTED FY 1968-FY 1970			$ SUPPORT FEDERAL & NON-FED.	PROJECT TITLE, PRINCIPAL INVESTIGATOR, AND PERFORMING ORGANIZATION
		8	9	0		
FISCAL YEAR 1968 GRANTS AND CONTRACTS:						
C-1008 (1572)	2E	x			$ 59,335 -	Experimental and theoretical study of the hydrodynamics of dispersion in rivers and estuaries - Tulin, Elata: Hydronautics, Inc., Laurel, Maryland
C-1018 (1573)	5G	x			54,900 -	A three dimensional study of parameters related to the current distribution in Lake Roosevelt - Jaske: Battelle Memorial Institute, Richland, Washington
C-1023 (1574)	6D	x	x		51,876 5,908	Multistructural demand models for water requirement forecasting - Reid: University of Oklahoma, Norman, Oklahoma
C-1034 (1575)	6A	x	x	x	51,236 3,843	Stochastic models for water resources management - Loucks: Cornell University, Ithaca, New York
C-1069 (1576)	6B	x	x		60,938 2,720	Optimum linear synthesis in urban hydrology - Eagleson: Massachusetts Institute of Technology, Cambridge, Massachusetts
C-1080 (1577)	6A	x	x	x	76,000 4,295	An optimal water management plan for the Miami Valley - Day, Shane: Carneigie Mellon University, Pittsburgh, Pennsylvania
C-1082 (1578)	6D	x	x		46,084 2,651	Applied criteria for municipal water rate structures - Kafoglis, Keig: University of Florida, Gainesville, Florida
C-1084 (1579)	6A	x			51,248 -	Systems approach to water resource management - Woods: TRW Systems, San Bernardino, California
C-1098 (1580)	4C	x			24,282 -	Evaluation of hydrologic effects of urbanization - Espey: Tracor, Inc., Austin, Texas

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1/ The number in parentheses, below the project number, is the grant or contract number.

2/ Indicates water resources research categories as developed and defined by the Federal Council for Science and Technology (FCST), Committee on Water Resources Research. These categories and subcategories are set forth in a separate appendix to this report.

1/ PROJ. NO.	2/ FCST CAT.	YEARS SUPPORTED FY 1968-FY 1970			$ SUPPORT FEDERAL & NON-FED.	PROJECT TITLE, PRINCIPAL INVESTIGATOR, AND PERFORMING ORGANIZATION
		8	9	0		
C-1102 (1581)	6B	x			$82,632 -	The economic value of water in industrial uses - Hotz, Bramer: Cyrus Wm. Rice & Company, Pittsburgh, Pennsylvania
C-1105 (1582)	6A	x	x		122,237 34,863	Application of simulation theory to water resources planning and management - Maxey: University of Nevada, Reno, Nevada
C-1114 (1583)	6E	x	x		64,553 4,807	Benefits from integrated water management in the New York Metropolitan region - Zobler: Barnard College, New York, New York
C-1120 (1584)	6F	x	x	x	21,418 1,295	Rational investment behavior in the face of floods: Theoretical and empirical studies of stochastic models for the analysis of flood control and relief policies - McGuire: University of California, Berkeley, California
C-1123 (1585)	6A	x	x		87,000 -	Systematic study and development of long-range programs of urban water resources research - McPherson, Taylor: American Society of Civil Engineers, New York, New York
C-1126 (1586)	6A	x	x	x	66,000 43,350	The use of systems analysis in the development of water resources management plans for New York State - Tedrow: New York State Conservation Department, Albany, New York
C-1136 (1521)	6A	x			89,653 -	A system approach for integrating groundwater and surface-water use - Mitchell: Aerojet-General Corporation, Azusa, California
C-1140 (1588)	6B	x	x	x	87,779 10,353	Decision making under uncertainty: Economic evaluation of streamflow forecasts- Schramm: University of Michigan, Ann Arbor, Michigan
C-1142 (1589)	6E	x	x	x	72,381 4,365	Urban water politics and decision making in the Detroit Metropolitan region- Walker, Wengert: University of Michigan, Ann Arbor, Michigan
C-1146 (1590)	2E	x	x	x	99,554 26,249	Systems approach to flow prediction in water resource planning - Chiu, Quimpo: University of Pittsburgh, Pittsburgh, Pennsylvania
C-1158 (1591)	2L	x	x	x	89,524 5,732	Horizontal dispersion in shallow estuaries of irregular shape - Masch, Moore: University of Texas, Austin, Texas
C-1159 (1592)	6A	x	x	x	73,060 4,500	Adapting the water resource planning process to problems and needs of metropolitan areas - Hufschmidt: University of North Carolina, Chapel Hill, North Carolina

1/ PROJ. NO.	2/ FCST CAT.	YEARS SUPPORTED FY 1968-FY 1970 8	9	0	$ SUPPORT FEDERAL & NON- FED.	PROJECT TITLE, PRINCIPAL INVESTIGATOR, AND PERFORMING ORGANIZATION
C-1184 (1593)	6A	x			$ 72,636 -	Development of computer models and methodology for forecasting and evaluating municipal and industrial water requirements - Greenberg: Hittman Associates, Inc., Baltimore, Maryland
C-1185 (1594)	6A	x	x		97,263 -	Development and implementation of a research strategy for water resources research - Gayer: Travelers Research Center, Inc., Hartford, Connecticut
C-1187 (1595)	4A	x	x		122,000 -	Water reservoir systems - Kalvinskas: North American Aviation, Anaheim, California
C-1202 (1596)	6D	x	x		35,386 3,500	Forecasting water demand: An inter- and intra-community study - Saunders: West Virginia University, Morgantown, West Virginia
C-1214 (1597)	2L	x			34,900 25,375	Utilization of physical and mathematical models in marine water resources research and management - Hargis: Virginia Institute of Marine Science, Gloucester Point, Virginia
C-1217 (1598)	6B	x			18,760 -	Estimation of recreational benefits at some existing water development sites in California - Merewitz: Planmetrics, Inc. San Francisco, California
C-1220 (1599)	6B	x	x	x	34,250 37,226	Economic Consequences of interbasin water transfers - Brown, Castle: Oregon State University, Corvallis, Oregon
C-1227 (1600)	6B	x	x	x	55,410 12,130	Introduction of risk and uncertainty concepts to optimization of water resource system design - Freund: Texas A&M University, College Station, Texas
C-1228 (1601)	6E	x	x	x	80,000 4,200	Institutional design for water quality management: A case study of the Wisconsin River Basin - Fox: University of Wisconsin, Madison, Wisconsin
C-1239 (1602)	6B	x	x	x	17,700 18,500	Economics of flood control structures in the lower Minnesota River watershed district - Samstad: Lower Minnesota River Watershed District, Burnsville, Minnesota
FISCAL YEAR 1969 GRANTS AND CONTRACTS:						
C-1032 (1962)	6A		x	x	31,694 3,478	Modeling and optimization of water resources systems - Lee, Fan: Kansas State University, Manhattan, Kansas

1/ PROJ. NO.	2/ FCST CAT.	YEARS SUPPORTED FY 1968-FY 1970			$ SUPPORT FEDERAL & NON-FED.	PROJECT TITLE, PRINCIPAL INVESTIGATOR, AND PERFORMING ORGANIZATION
		8	9	0		
C-1196 (1963)	6A		x	x	$ 29,950 1,780	Government institutional arrangements and allied law to facilitate water and related land resources planning, development and operational management: I, A study of potential institutional arrangements for water pollution control in the Hudson-Mohawk River - Dworsky: Cornell University, Ithaca, New York
C-1282 (1964)	2E		x	x	44,489 2,340	Computer analysis of watershed characteristics affecting flood hydrology - James: University of Kentucky, Lexington, Kentucky
C-1290 (1965)	2A		x	x	61,000 -	Experimental and theoretical study of the hydrodynamics of dispersion in rivers and estuaries, Phase II - Elata: Hydronautics, Laurel, Maryland
C-1314 (1966)	6B		x	x	31,548 2,563	Evaluation of natural river environments - Morisawa: Antioch College, Yellow Springs, Ohio
C-1318 (1967)	6A		x	x	11,732 1,100	Stochastic basis for comprehensive river basin planning - Haag: Union College, Schenectady, New York
C-1321 (1968)	6A		x	x	39,716 2,202	Analysis of the decision sequence in water resource planning - Linsley: Stanford University, Stanford, California
C-1323 (1969)	6B		x	x	78,400 6,000	Case study of remedial flood management in an urban area, Phase I - Kindsvater: Georgia Institute of Technology, Atlanta, Georgia
C-1337 (1970)	6B		x	x	55,000 3,000	Research and analysis to plan, develop, and manage a ground and surface water supply - Butcher: University of Nevada, Reno, Nevada
C-1339 (1971)	4B		x	x	67,400 -	Hydrologic analysis of groundwater basins by digital computer simulation - Meyer, Kleinecke: General Electric TEMPO, Santa Barbara, California
C-1357 (1972)	6E		x	x	48,697 -	Comprehensive planning for water resources management in metropolitan environments - Knetsch: George Washington University, Washington, D.C.
C-1361 (1973)	5G		x	x	46,680 3,181	Soil and water management for salinity control - Stucky: New Mexico State University, Las Cruces, New Mexico
C-1370 (1974)	6E		x	x	71,700 -	Analysis of managerial, financial, and regulatory functions of regional water resources authorities and other institutional arrangements - Messer: Booz, Allen and Hamilton, Inc., Washington, D.C.

1/ PROJ. NO.	2/ FCST CAT.	YEARS SUPPORTED FY 1968-FY 1970			$ SUPPORT FEDERAL & NON- FED.	PROJECT TITLE, PRINCIPAL INVESTIGATOR, AND PERFORMING ORGANIZATION
		8	9	0		
C-1377 (1975)	6A		x	x	$100,000 100,000	Systems simulation for management of a total water resource - Meier, Weiss: Texas Water Development Board, Austin, Texas
C-1388 (1976)	6F		x		7,777 639	Economic implications of the interconnection of urban water systems - Seidenstat: Temple University, Philadelphia, Pennsylvania
C-1396 (1977)	6D		x	x	128,819 -	Development of a refined predictive system for use in forecasting municipal water needs - Leibowitz: Hittman Associates, Inc., Baltimore, Maryland
C-1397 (1991)	3D		x	x	84,362 -	Develop a computerized methodology for evaluation of municipal water conservation research programs - Greenberg: Hittman Associates, Inc., Baltimore, Maryland
C-1401 (1979)	6G		x	x	75,000 50,095	The effects of thermal loading and water quality on estuarine primary production - Mihursky, Flemmer: University of Maryland, College Park, Maryland
C-1410 (1980)	6A		x	x	88,934 -	A generalized, probabilistic approach to regional water supply assessment - Dracup: Environmental Dynamics, Inc., Los Angeles, California
C-1414 (1981)	9A		x	x	47,235 -	Supply of and demand for trained water resources personnel: A pilot study - Boek: Surveys & Research Corporation, Washington, D.C
C-1415 (1982)	6A		x	x	228,906 -	Research on data and analytical systems for preparing national water assessments - Wilkinson: Arthur D. Little, Inc., Cambridge, Massachusetts
C-1428 (1983)	6G		x	x	15,225 -	Utilization of physical and mathematical models in estuarine water resources research and management (a continuation project) - Hargis: Virginia Institute of Marine Science, Gloucester Point, Virginia
C-1443 (1984)	6E		x	x	31,893 15,502	Social change in a water resource development area: Social aspects of the construction phase of Libby Dam - Tureck: Montana State University, Bozeman, Montana
C-1469 (1985)	4C		x	x	95,137 -	Water and the cities-Miller; Abt Associates, Cambridge, Massachusetts
C-1477 (1986)	6B		x	x	75,800 -	Development of methods for valuing wild rivers - Orlob: Water Resources Engineers, Inc., Walnut Creek, California

1/ PROJ. NO.	2/ FCST CAT.	YEARS SUPPORTED FY 1968-FY 1970 8	9	0	$ SUPPORT FEDERAL & NON-FED.	PROJECT TITLE, PRINCIPAL INVESTIGATOR, AND PERFORMING ORGANIZATION
C-1484 (1987)	2H		x	x	$ 40,000 -	Diatom populations changes in Lake George - Clesceri: Rensselaer Polytechnic Institute, Troy, New York
C-1495 (1988)	8A		x	x	28,000 1,060	A generalized computer language for hydrologic and hydraulic analysis - Perkins: Massachusetts Institute of Technology, Cambridge, Massachusetts
C-1496 (1989)	6E		x	x	75,000 -	Systematic analysis of management effectiveness of the water quality control board system of California - Harmon: Engineering-Science, Inc., Arcadia, California
C-1511 (1990)	6B		x	x	76,648 -	A continuation of the study to determine the costs of water in industrial uses - Bramer, Motz: Cyrus Wm. Rice & Company, Pittsburgh, Pennsylvania
C-1536 (1992)	6A		x	x	84,400 -	Systematic study and development of long-range programs of urban water resources research - Taylor, McPherson: American Society of Civil Engineers, New York, New York
C-1537 (1993)	4B		x	x	98,578 18,213	Mathematical management model unconfined aquifer - Rayner, Wells: Texas Technological College, Lubbock, Texas
FISCAL YEAR 1970 GRANTS AND CONTRACTS:						
C-1195 (3144)	6E			x	37,600 -	Integrated management and administration of ground water in interstate and international aquifers - Phase I - Bittinger & Moses: Morton W. Bittinger and Associates, Fort Collins, Colorado
C-1602 (3145)	6A			x	72,082 15,240	Systems analysis of the Great Lakes - Deininger: University of Michigan, Ann Arbor, Michigan
C-1613 (3146)	2F			x	21,170 14,420	Statistical geometry of porous media - Scheidegger: University of Illinois, Urbana, Illinois
C-1629 (3147)	6A			x	76,562 5,685	Coordinated management and design of area water supply and waste water disposal networks: A linked systems analysis, Zobler; Barnard College New York, New York
C-1630 (3148)	3C			x	46,223 3,130	Soil and water management for salinity control - Phase II - Wiersma: New Mexico State University, Las Cruces, New Mexico

1/ PROJ. NO.	2/ FCST CAT.	YEARS SUPPORTED FY 1968-FY 1970			$SUPPORT FEDERAL & NON-FED.	PROJECT TITLE, PRINCIPAL INVESTIGATOR, AND PERFORMING ORGANIZATION
		8	9	0		
C-1633 (3149)	6B			x	$ 59,996 -	Socio-economic study of multiple use water supply reservoir - Stone: Ralph Stone and Co., Inc., Los Angeles, California
C-1635 (3150)	6A			x	38,954 2,050	Evaluation of the decision process in water resource planning- Phase I: Linsley: Stanford University, Stanford, California
C-1640 (3151)	6A			x	67,255 8,757	Metropolitan water resources systems analysis - Loucks: Cornell University, Ithaca, New York
C-1649 (3152)	6A			x	36,650 5,207	Modeling and optimization of water resource systems, Phase II - Lee: Kansas State University, Manhattan, Kansas
C-1663 (3153)	5C			x	73,604 13,108	An ecological evaluation of stream eutrophication - Ball: Michigan State University, East Lansing, Michigan
C-1668 (3154)	6A			x	49,886 3,476	Optimization of water resources development: Phase III, Yeh: University of California, Riverside, California
C-1671 (3155)	2A			x	60,000 -	Experimental and theoretical study of the hydronamics of dispersion in rivers and estuaries, Phase III - Tulin, Elata: Hydronautics, Inc., Laurel, Md.
C-1681 (3156)	6A			x	85,000 106,000	Stochastic optimization and simulation techniques for management of regional water resource systems - Weiss & Meier: Texas Water Development Board, Austin
C-1702 (3157)	6A			x	18,256 2,083	Continuation of stochastic basis for comprehensive river basin planning, Phase II - Haag: Union College, Schenectady, New York
C-1706 (3158)	2A			x	38,461 1,900	Optimum linear synthesis in urban hydrology, Phase II - Eagleson: Massachusetts Institute of Technology, Cambridge, Massachusetts
C-1708 (3159)	8A			x	49,345 2,000	A problem oriented language for hydrologic analysis - Perkins: Massachusetts Institute of Technology, Cambridge, Massachusetts
C-1713 (3160)	6B			x	48,716 3,593	Economic evaluation of various uses and cost allocation of surface water resources - Andrews and Weyrick: University of New Hampshire, Durham, New Hampshire

1/ PROJ. NO.	2/ FCST CAT.	YEARS SUPPORTED FY 1968-FY 1970 8	 9	 0	$SUPPORT FEDERAL & NON-FED.	PROJECT TITLE, PRINCIPAL INVESTIGATOR, AND PERFORMING ORGANIZATION
C-1717 (3161)	5C			x	$ 47,000 -	Diatom populations changes in Lake George: Phase II - Clesceri: Rensselaer Polytechnic Institute, Troy, New York
C-1725 (3162)	8C			x	81,828 -	Mathematical modeling of water distribution systems - Gilman: General Electric Co., Philadelphia, Pennsylvania
C-1736 (3163)	6E			x	79,420 -	Decision processes in water quality management - Jensen, Males: Engineering Science, Inc., Arcadia, California
C-1743 (3164)	5G			x	80,000 -	A multi-phasic component study to predict storm water pollution from urban areas - Walters: AVCO Economic Systems Corp., Washington, D.C.
C-1748 (3165)	6E			x	16,845 -	Implementation of water resources plans in metropolitan environments - Knetsch: George Washington University, Washington, D.C.
C-1786 (3167)	6B			x	60,000 5,100	Case study of remedial flood management in an urban area, Phase II - Kindsvater: Georgia Institute of Technology, Atlanta, Georgia
C-1790 (3168)	6B			x	75,000 -	Factorial analysis of price-demand and demand-cost functions for municipal water systems- Boland: Hittman Associates, Inc., Columbia, Maryland
C-1804 (1992)	2E			x	50,000 -	Systematic study and development of long range programs of urban water resources research - McPherson, Taylor: American Society of Civil Engineers, New York, New York
C-1817 (3170)	6G			x	78,546 13,766	Water cycles, water resources planning and urban development at Rookery Bay, Florida - Dasmann, Tabb: Conservation Foundation, Washington, D.C.
C-1818 (3171)	6B			x	45,063 21,800	Evaluation of recreational and cultural benefits of estuarine use in an urban setting - Van Tassel: Hofstra University, Hempstead, New York
C-1819 (3172)	5G			x	29,000 9,682	Computer simulation of eutrophication - Bella: Oregon State University, Corvallis, Oregon
C-1872 (3173)	6B			x	55,000 3,010	Research and analysis to plan, develop, and manage a ground and surface water supply, Phase II - Butcher: Desert Research Institute, Reno, Nevada

1/ PROJ. NO.	2/ FCST CAT.	YEARS SUPPORTED FY 1968-FY 1970			$ SUPPORT FEDERAL & NON-FED.	PROJECT TITLE, PRINCIPAL INVESTIGATOR, AND PERFORMING ORGANIZATION
		8	9	0		
C-1874 (3174)	6E			x	$ 63,100 30,000	Coordination of public and private forces on inland lake and shoreline management - Fulton: Huron River Watershed Council, Ann Arbor, Michigan
C-1875 (3175)	2F			x	60,000 -	Mathematical modeling of fresh water acquifers having salt water bottoms - Kleinecke and Meyer: General Electric Co., Santa Barbara, California
C-1892 (3176)	6A			x	75,000 -	Water as a potential organizing concept in urban regions - Meltzer, Sheaffer: University of Chicago, Chicago, Illinois
C-1912 (3177)	6B			x	68,800 -	Economic and institutional analysis of a waste water reclamation and reuse project - Banks & Inerfield: Leeds, Hill & Jewett, San Francisco, California
C-1914 (3178)	6A			x	67,870 -	Evaluating urban core usage of waterways and shorelines - Whitman: Battelle Memorial Institute, Columbus, Ohio
C-1919 (3179)	6A			x	60,000 3,240	Application of simulation theory to water resources planning and management-Butcher: Desert Research Institute, Reno, Nevada

APPENDIX M

Water Resources Research Categories

(Reprinted from Appendix A, pages 78-82, of "A Ten-Year Program of Federal Water Resources Research," a report of the Federal Council for Science and Technology Committee on Water Resources Research, February 1966.)

I. NATURE OF WATER

Category I deals with fundamental research on the water substance.

A. *Properties of water*—Study of the physical and chemical properties of pure water and its thermodynamic behavior in its various states.

B. *Aqueous solutions and suspensions*—Study of the effects of various solutes on the properties of water; surface interactions; colloidal suspensions.

II. WATER CYCLE

Category II covers generally research on the natural processes involving water. It is an essential supporting effort to applied problems in later categories.

A. *General*—Studies involving two or more phases of the water cycle such as hydrologic models; rainfall-runoff relations; surface and groundwater relationships; watershed studies, etc.

B. *Precipitation*—Investigation of spatial and temporal variations of precipitation; physiographic effects; time trends; extremes; probable maximum precipitation; structure of storms, etc.

C. *Snow, ice, and frost*—Studies of the occurrence and thermodynamics of water in the solid state in nature; spatial variations of snow and frost; formation of ice and frost; breakup of river and lake ice; glaciers, permafrost, etc.

D. *Evaporation and transpiration*—Investigation of the process of evaporation from lakes, soil, and snow and of the transpiration process in plants; methods of estimating actual evapotranspiration; energy balance; etc.

E. *Streamflow*—Mechanics of flow in streams; flood routing; bank storage; space and time variations (includes high and low-flow frequency); droughts; floods, etc.

F. *Groundwater*—Study of the mechanics of groundwater movements; multiphase systems; sources of natural recharge; mechanics of flow to wells and drains; subsidence; properties of aquifers; etc.

G. *Water in soils*—Infiltration, movement and storage of water in the zone of aeration, including soil.

H. *Lakes*—Hydrologic, hydrochemical, and thermal regimes of lakes; water level fluctuations; currents and waves.

I. *Water and plants*—Role of plants in hydrologic cycle; water requirements of plants; interception.

J. *Erosion and sedimentation*—Studies of the erosion process; prediction of sediment yield; sedimentation in lakes and reservoirs; stream erosion; sediment transport, etc.

K. *Chemical processes*—Chemical interactions between water and its natural environment; chemistry of precipitation.

L. *Estuarine problems*—Special problems of the estuarine environment; effect of tides on flow and stage; deposition of sediments; sea water intrusion in estuaries.

III. WATER SUPPLY AUGMENTATION AND CONSERVATION

As water use increases we must pay increasing attention to methods for augmenting and conserving available supplies. Research in Category III is largely applied research devoted to this problem area.

A. *Saline water conversion*—Research and development related to methods of desalting sea water and brackish water.

B. *Water yield improvement*—Increasing streamflow or improving its distribution through land management; water harvesting from impervious areas; phreatophyte control; reservoir evaporation suppression.

C. *Use of water of impaired quality*—Research on methods of agricultural use of water of high salinity; use of poor quality water in industry crop tolerance to salinity.

D. *Conservation in domestic use*—Methods for reducing domestic water needs without impairment of service.

E. *Conservation in industry*—Reduction in both consumption and diversion requirements for industry.

F. *Conservation in agriculture*—More efficient irrigation practices. Chemical control of evaporation and transpiration; lower water use plants, etc.

IV. WATER QUANTITY MANAGEMENT AND CONTROL

Category IV includes research directed to the management of water, exclusive of conservation, and the effects of related activities on water.

A. *Control of water on the land*—Effects of land management on runoff; land drainage; potholes; etc.

B. *Groundwater management*—Artificial recharge; conjunctive operation; relation to irrigation.

C. *Effects of man's related activities on water*—Impact of urbanization, highways, logging, etc., on water yields and flow rates.

D. *Watershed protection*—Methods of controlling erosion to reduce sediment load of streams and conserve soil.

V. WATER QUALITY MANAGEMENT AND PROTECTION

An increasing population increases the wastes and other pollutants entering our water supplies. Category V deals with methods of identifying, describing and controlling this pollution.

A. *Identification of pollutants*—Techniques of identification of physical, chemical and biologic pollutants; rational measures of character and strength of wastes.

B. *Sources and fate of pollution*—Determination of the sources of pollutants in water; the nature of the pollution from various sources; path of pollutant from source to stream or groundwater.

C. *Effects of pollution*—Definition of the effect of pollutants, singly and in combination, on man, aquatic life, agriculture and industry under conditions of sustained use; eutrophication.

D. *Waste treatment processes*—Research to improve conventional treatment methods to gain efficiency or reduce cost; processes to treat new types of waste; advanced treatment methods for more complete removal of pollutants including purification for direct reuse.

E. *Ultimate disposal of wastes*—Disposal of residual material removed from water and sewage during the treatment process; disposal of waste brines.

F. *Water treatment*—Development of more efficient and economical methods of making water suitable for domestic or industrial use.

G. *Water quality control*—Research on methods to control stream and reservoir water quality such as flow augmentation; stream and reservoir aeration; control of natural pollution; control of pollution from pesticides and agricultural chemicals; control of acid mine drainage; etc.

VI. WATER RESOURCES PLANNING

The problems of achieving an optimal plan of water development are becoming increasingly complex. Category VI covers research devoted to determining the best way to plan, the appropriate criteria for planning and the nature of the economic legal and institutional aspects of the planning process.

A. *Techniques of planning*—Application of systems analysis to project planning; treatment of uncertainty; probability studies.

B. *Evaluation process*—Development of methods, concepts and criteria for evaluating project benefits; discount rate; project life; methods for economic, social and technological projections; reliability of projections; research on the value of water in various uses.

C. *Cost allocation, cost sharing, pricing/repayment*—Research on methods of calculating repayment and establishing prices for vendible products; techniques of cost allocation; cost sharing, pricing and repayment policy.

D. *Water demand*—Research on the water quantity and quality requirements of various uses, both diversion and consumption.

E. *Water law and institutions*—A study of state and Federal water law looking to changes and additions which will encourage greater efficiency in use; investigation of institutional structures and constraints which influence decisions on water at all levels of government.

F. *Nonstructural alternatives*—Exploration of methods to achieve water development aims by nonstructural methods such as flood plain zoning.

G. *Ecologic impact of water development*—Effects of water management operations on overall ecology of the area. Excludes effect of pollution under V–C.

VII. Resources Data

Planing and management of our water resources require information. Category VII includes research oriented to data needs and the most efficient methods of meeting these needs.

A. *Network design*—Studies of data requirements and of the most effective methods of collecting the data.

B. *Data acquisition*—Research on new and improved instruments and techniques for collection of water resources data; telemetering equipment.

C. *Evaluation, processing and publication*—Studies of effective methods of processing data, form and nature of published data; maps of data.

VIII. Engineering Works

To implement water development plans requires engineering works. Category VIII describes research on design, materials and construction which is generally useful to all aspects of water management. Works relevant to a single specific goal, such as water treatment or desalination, are included elsewhere if an appropriate category exists.

A. *Design*—Research leading to improved design of dams, canals, pipelines, locks, fishways and other works required for water resource development.

B. *Materials*—Research to improve existing structural materials and to develop new materials; subsurface exploration of foundations; corrosion; etc.

C. *Construction and operation*—Research on efficient construction methods, operating systems, and maintenance procedures.

IX. Manpower, Grants and Facilities

Trained manpower is an essential ingredient of research on water resources and the planning and design of water development projects. Category IX describes plans for support of education and training. It also includes grant and contract programs for which advance distribution to specific categories is impossible.

A. *Education—extramural*—Support of education in water resources at universities (not including research support under other categories).

B. *Education—in-house*—Government employee training programs.

C. *Research facilities*—Laboratories, field stations, etc.

D. *Grants, contracts and research act allotments*—Allotments to University Water Resources Research Institutes under P.L. 88-379; OWRR, HEW, NSF, CSRS, and other grants which cannot be distributed to categories in advance.

APPENDIX N

SUMMARY OF ANNUAL ALLOTMENT (SECTION 100) PROJECTS BY FCST RESEARCH CATEGORIES FOR FISCAL YEARS 1965 THRU 1970 1/

FCST RESEARCH CATEGORY OR ITEM	FY 1965 - 1969			FY 1969			FY 1970			TOTAL			NO. OF SEPARATE PROJECTS SUPPORTED FY-1965-1970
	No.	$ Amount	%	No.	$Amount	%	No.	$ Amount	%	No.	$ Amount	%	
I	26	171,543	1.3	16	129,113	3.2	16	139,410	3.6	58	440,066	2.1	25
II	270	2,018,101	14.9	103	809,476	20.1	105	775,998	20.1	478	3,603,575	16.8	232
III	143	1,279,781	9.4	26	266,268	6.6	15	134,829	3.5	184	1,680,878	7.8	68
IV	158	1,690,612	12.5	27	316,660	7.9	18	224,669	5.8	203	2,231,941	10.4	77
V	617	4,891,583	36.1	185	1,514,389	37.7	192	1,571,369	40.9	994	7,977,341	37.2	433
VI	322	2,689,976	19.8	101	789,332	19.7	92	872,473	22.6	515	4,351,781	20.4	250
VII	70	599,862	4.4	15	113,986	2.8	10	65,969	1.7	95	779,817	3.6	43
VIII	41	214,677	1.6	12	71,590	1.8	10	70,570	1.8	63	356,837	1.7	32
IX	2	6,822	-	2	7,822	.2	-	-	-	4	14,644	-	2
Sub-total	1649	13,562,957	100	487	4,018,636	100	458	3,855,287	100	2594	21,436,880	100	1162
Reserve	-	-	-	-	-	-	-	144,366	-	-	144,366	-	-
Director's Office	-	3,447,032	-	-	1,081,364	-	-	1,100,347	-	-	5,628,743	-	-
TOTAL	1649	17,009,989	-	487	5,100,000	-	458	5,100,000	-	2594	27,209,989	-	1162

1/ UNDER THE SEC.100 ANNUAL ALLOTMENT PROGRAM, PROJECTS ARE FUNDED FROM CURRENT YEAR FUNDS ON A YEAR-TO-YEAR BASIS: THEREFORE, IN COLUMNS (2) THROUGH (5) OF THIS SUMMARY, A PROJECT IS COUNTED ONCE IN THE "No." SUBCOLUMN FOR EACH FISCAL YEAR THAT IT WAS FUNDED. HOWEVER, COLUMN (6) SHOWS THE TOTAL NUMBER OF SEPARATE PROJECTS FUNDED DURING THE FISCAL YEAR 1965 - 1970 PERIOD REGARDLESS OF THE NUMBER OF YEARS SUCH PROJECTS MAY HAVE RECEIVED OWRR FUND SUPPORT.

APPENDIX O

OFFICE OF WATER RESOURCES RESEARCH

SUMMARY OF MATCHING GRANTS (SECTION 101) PROJECTS BY FCST RESEARCH CATEGORIES FOR FISCAL YEARS 1965 THRU 1970

FCST RESEARCH CATEGORY OR ITEM	FY 1965 - 1968			FY 1969			FY 1970			TOTAL		
	No.	$ AMOUNT	%	No.	$ AMOUNT	%	No.	$ AMOUNT	%	No.	$ AMOUNT	%
I	1	9,086	-	-	-	-	1	4,465	-	2	13,551	-
II	39	1,005,499	15.0	33	925,130	30.8	17	574,631	19.2	89	2,505,260	19.6
III	16	631,895	9.4	6	195,193	6.5	4	121,683	4.1	26	948,771	7.4
IV	46	999,879	14.9	5	111,664	3.7	3	87,894	2.9	54	1,199,437	9.4
V	67	1,772,369	26.2	20	691,310	23.0	17	511,165	17.1	104	2,974,844	23.5
VI	75	1,993,289	29.5	24	966,153	32.2	51	1,700,162	56.7	150	4,659,604	36.6
VII	9	198,163	3.0	1	82,950	2.8	-	-	-	10	281,113	2.2
VIII	7	139,820	2.0	2	27,600	1.0	-	-	-	9	167,420	1.3
IX	-	-	-	-	-	-	-	-	-	-	-	-
FEDERAL FUNDS	260	6,750,000	100%	91	3,000,000	100%	93	3,000,000	100%	444	12,750,000	100%
NON-FEDERAL FUNDS	-	7,401,329	-	-	3,184,551	-	-	3,372,872	-	-	13,958,752	-
TOTAL	260	14,151,329	-	91	6,184,551	-	93	6,372,872	-	444	26,708,752	-

APPENDIX P

OFFICE OF WATER RESOURCES RESEARCH

SUMMARY OF TITLE II RESEARCH PROJECTS
BY FCST RESEARCH CATEGORIES
FOR FISCAL YEARS 1968 THRU 1970

FCST RESEARCH CATEGORY OR ITEM	FY 1968			FY 1969			FY 1970			TOTAL		
	No.	$ AMOUNT	%	No.	$ AMOUNT	%	No.	$ AMOUNT	%	No.	$ AMOUNT	%
I	-	-	-	--	-	-	-	-	-	-	-	-
II	4	283,313	14.1	3	145,489	7.2	5	229,631	11.4	12	658,433	10.9
III	-	-	-	1	84,362	4.3	1	46,223	2.4	2	130,585	2.2
IV	2	146,282	7.4	3	261,115	13.0	-	-	-	5	407,397	6.8
V	1	54,900	2.7	1	46,680	2.3	4	229,604	11.4	6	331,184	5.6
VI	24	1,515,500	75.8	21	1,386,839	69.3	24	1,358,968	69.7	69	4,261,307	71.1
VII	-	-	-	-	-	-	-	-	-	-	-	-
VIII	-	-	-	1	28,000	1.5	2	131,173	6.7	3	159,173	2.6
IX	-	-	-	1	47,235	2.4	-	-	-	1	47,235	.8
Sub-Total	31	1,999,995	100%	31	1,999,720	100%	36	1,995,599	98.8	98	5,995,314	100%
Uncommitted		5	-		280	-		4,401	.2		4,686	-
TOTAL	31	2,000,000	100%	31	2,000,000	100%	36	2,000,000	100%	98	6,000,000	100%

APPENDIX Q

PUBLICATIONS AND THESES RELATING TO WATER RESOURCES RESEARCH PROGRAM ACTIVITIES SUPPORTED WHOLLY OR IN PART BY P.L. 88-379 FUNDS [1]

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[1] Title I publications and theses are listed by States and, when pertinent, specific projects on which they are based, are listed, by numbers, in parentheses. Publications based on Title II research projects are listed by number. Water-related publications by OWRR are listed also. Readers interested in obtaining copies of, or additional information about, publications produced by the respective State Water Resources Research Institutes are advised to write directly to the Institutes. (See Appendix S for addresses.)

ALABAMA

Publications

Cairns, E. J., E. K. Mercer, and T. W. Merritt
1968. Nematudes in Alabama water resources. Highlights of Agricultural Research. Auburn University Agricultural Experiment Station. (A-004-ALA)

Chan, D. T., and J. G. Hendrick
1968. Using a cone penetrometer to predict soil density and hydraulic conductivity. Paper H39 presented at the Seventh National Fall Meeting of the American Geophysical Union at San Francisco, California. (A-005-ALA)

Dinius, R. H., J. F. Judkins, L. J. Hirth, and J. C. Farrow
1969. Gamma irradiation as a treatment process for textile waste. American Chemical Society. In press. (A-012-ALA)

Dinius, Robert H., and J. W. Woolfolk
1969. Titrimetric determination of dissolved oxygen. Microchemical Journal 14 (1). (B-001-ALA)

Dusi, J. L.
1969. Population fluctuations in a heron nesting colony. Alabama Journal of Science. In press. (A-010-ALA)

Dusi, J. L. and R. T. Dusi
1968. (a) Ecological factors contributing to nesting failure in a heron colony. Wilson Bulletin. Volume 80, Number 4, pages 458-466. (A-010-ALA)

(b) Evidence for the breeding of the wood stork in Alabama, 1968. Alabama Birdlife. Volume 16, Number 23, pages 14-16. (A-010-ALA)

Hendrick, J. G.
1968. X-Y plotter strain-gage input coupler. Agricultural Engineering Volume 49, Number 10, pages 608-609. (A-005-ALA)

1969. Recording penetrometer. Journal of Agricultural Engineering Research. In press. (A-005-ALA)

Hung, G. W. and R. H. Dinius
1969. Diffusivity of oxygen in aqueous electrolyte solution. American Chemical Society. In press.

Koon, J. L., J. G. Hendrick and R. E. Hermanson
1968. Some effects of soil surface cover on infiltration. Paper H38 presented at the Seventh National Fall Meeting of the American Geophysical Union at San Francisco, California. (A-005-ALA)

Lawrence, J. M.
1969. Comparative concentrations of selected macro and micro nutrients in water, suspended matter, hydrosol, plants, and fish from reservoirs on Chattahoochee river. Proceedings of the Fourth Annual American Water Resources Conference. Pages 368-378. (B-010-ALA)

Leigh, Gerald M.
1969. Degradation of selected chlorinated hydrocarbon insecticides. Journal Water Pollution Control Federation. In press. (A-002-ALA)

Merritt, T. W. and E. J. Cairns
1969. Ecology of nematodes in a small fresh-water pond. Abstract. Journal of Alabama Academy of Science. In press. (A-004-ALA)

Scarbrough, W. Leon, Thomas J. Joiner, and James C. Warman
1969. Electrical resistivity survey in the Piedmont Area, Alabama. Geological Survey of Alabama Circular 57. 20 pages.

Theses

Burks, Robert L.
1968. An economic analysis of water resources use and use conflicts of selected industry groups in Alabama with respect to area development. M. S. thesis. Auburn University, Auburn, Alabama. 111 pages. (B-012-ALA)

Davidson, G. R., Jr.
1968. A study of color removal from textile dye wastes by chemical coagulation. M. S. thesis. Auburn University, Auburn, Alabama. 48 pages. (A-011-ALA)

Kelley, James C.
1969. A geologic study of the Chattanooga Shale in the Elkmont Quadrangle, Alabama. M. S. thesis. University of Alabama. 43 pages. (B-007-ALA)

Smith, R. E.
1969. Nematocidal activity of a cyanogenic *Chromobacterium* species. M. S. thesis, Auburn University, Auburn, Alabama. 80 pages. (A-006-ALA)

Sonderegger, John L.
1969. A photogeologic and structural study of a limestone terrane with emphasis on fractures affecting ground-water occurrence. M. S. thesis, University of Alabama. 28 pages. (B-007-ALA)

Wang, J. Y.
1969. Modification and calibration of H-flume and Coshocton wheel sampler. M. S. thesis. Auburn University, Auburn, Alabama. 88 pages. (A-005-ALA)

ALASKA

Publications

Benson, Carl S.
1969. Stratigraphic studies in the snow at Byrd Station, Antarctica, compared with similar studies in Greenland. Glaciological volume of the SGU Antarctica Research Series. In press. (A-012-ALAS)

1969. Comparative snow studies on the Antarctica and Greenland ice sheets. Proceedings of International Symposium on Antarctic Glaciological Exploration. In press. (A-012-ALAS)

Button, Don K.
1969. Thiamine limited steady state growth of the yeast *Cryptococcus albidus*. Journal of General Microbiology. In press. (A-007-ALAS)

Grube, Gareth A. and R. Sage Murphy
1969. Oxidation ditch operation in Alaska. Water and Sewage Works, July 1969. (A-014-ALAS)

Murphy, R. Sage
1969. Practical application of foam fractionation treatment of low quality water. Research Report No. IWR-9. Institute of Water Resources, University of Alaska. 11 pages. (A-024-ALAS)

Reed, Sherwood C. and R. Sage Murphy
1969. Low temperature activated sludge settling. Journal of the Sanitary Engineering Division, ASCE, Volume 95, Number SA4, pages 747-767. (A-014-ALAS)

Thesis

Miller, Ann P.
1969. The microbial decomposition of cellulose. M.S. thesis. University of Alaska. 43 pages. (A-014-ALAS)

ARIZONA

Publications

Duckstein, L., and C. C. Kisiel
1968. General systems approach to groundwater problems. Proceedings, National Symposium on the Analysis of Water-Resource Systems (Denver, Colorado, July 1968). Pages 100-115. (A-010-ARIZ)

Padfield, Harland, and Courtland Smith
1968. Water and culture: new decision rules for old institutions. Rocky Mountain Social Science Journal, Volume V, Number 2. Pages 23-32. (B-003-ARIZ)

Sariahmed, A., and C. C. Kisiel
1968. Synthesis of sequences of summer thunderstorm volumes for the Atterbury Watershed, Arizona. Proceedings, International Symposium on the Use of Analog and Digital Computers in Hydrology. Volume II, International Association of Scientific Hydrology Publication Number 81 (Tucson, Arizona, December 1968). Pages 439-447. (A-010-ARIZ)

Summer, J. S., and West, R. E.
1969. The University of Arizona's statewide gravity survey. Transactions, American Geophysical Union. In press. (A-008-ARIZ)

Dissertations and Theses

Bruner, John M.
1969. An analysis of municipal water demand in the Phoenix metropolitan area. Ph.D. dissertation. Arizona State University. (A-013-ARIZ)

Eiselein, E. B.
1969. Water for Weststate, USA: The association in the politics of water resource development. Ph.D. dissertation. University of Arizona. 271 pages. (B-003-ARIZ)

Foster, Kennith E.
1969. Mathematical analysis of a natural recharge mound. M.S. thesis. University of Arizona. (A-011-ARIZ)

Krapf, R. W.
1969. The influence of sodium chloride on hydraulic conductivity of some Arizona soils. M.S. thesis. University of Arizona. 56 pages. (B-005-ARIZ)

Lehman, G. S.
1968. Soil and grass filtration of domestic sewage effluent for the removal of trace elements. Ph.D. dissertation. University of Arizona. (A-011-ARIZ)

Powers, W. R. III
1969. The influence of sodium chloride and gravel treatments on infiltration. M.S. thesis. University of Arizona. 80 pages. (B-005-ARIZ)

Sariahmed, A.
1969. Synthesis of sequences of summer thunderstorm volumes for the Atterbury Watershed in the Tucson area. M.S. thesis. University of Arizona. 170 pages. (A-010-ARIZ)

Spangler, D. P.
1969. Geophysical survey of the Walnut Gulch Watershed, Cochise County, Arizona. Ph.D. dissertation. University of Arizona. (A-008-ARIZ)

ARKANSAS

Publications

Bacon, Edmond J. and Raj V. Kilambi
1968. Some aspects of the age and growth of the longear sunfish, *Lepomis megalotis*, in Arkansas waters. Proc. Ark. Acad. Sci. Volume 22, Pages 44-56. (A-007-ARK)

Bacon, Edmond J., William H. Neill, Jr., and Raj V. Kilambi
1967. Temperature selection and heat resistance of the mosquito fish, *Gambusia affinis*. Proceedings of the 21st Annual conference of the Southeastern Commissioners. Pages 411-416. (A-007-ARK)

Eley, Bruce W.
1969. Interim progress report on a eutrophication model of the White River Basin above Beaver Reservoir in northwest Arkansas. Arkansas Water Resources Research Center. University of Arkansas, Fayetteville, Arkansas. (B-012-ARK)

Hoskyn, J. P., B. B. Bryan, and G. W. Baker
1969. Forming orifices in plastic pipe. Arkansas Farm Research, Volume XVIII, No. 2. (A-002-ARK)

Hoskyn, John P. and Billy B. Bryan
1969. Subsurface irrigation research in Arkansas. Arkansas Water Resources Research Center, Publication No. 3, University of Arkansas, Fayetteville, Arkansas. (A-002-ARK)

Jeffus, H. M., J. A. Proctor, and L. R. Heiple
1968. Second interim progress report, water resources planning study for Arkansas and Oklahoma, Arkansas Water Resources Center. University of Arkansas, Fayetteville, Arkansas. (B-001-ARK)

Meyer. R. L.
1969. The freshwater algae of Arkansas. I. Introductions and recent additions. Proc. Ark. Acad. Sci. Volume 23. In press. (A-011-ARK)

Meyer, R. L., J. F. Brown, and R. A. Gearheart
1969. Cattle poisoning in northwest Arkansas related to the blue-green alga *Microcystis aeruginosa* Kutzing. Proc. Ark. Acad. Sci. Volume 23. In press.

Newton, Scott H. and Raj V. Kilambi
1969. Determination of sexual maturity of white bass from ovum diameters. Southwestern Naturalist, Volume 14, Number 2. In press. (A-007-ARK)

Theses

Kutumbarao, Tummala
1969. Dynamic filtration during laminar flow through a rectangular slot. M. S. thesis, University of Arkansas, Fayetteville. 84 pages. (B-004-ARK)

Owen, W. B., Jr.
1969. A continued pre- and postimpoundment survey of the helminth and crustacean parasites of *Micropterus dolomieui* (Lacepede), *M. punctulatus* (Rafinesque), and *M. salmoides* (Lacepede) (Perciformes) of Beaver Reservoir in northwestern Arkansas. M. S. thesis, University of Arkansas, Fayetteville. 57 pages. (A-009-ARK)

CALIFORNIA

Publications

Amorocho, Jr.
1967. (a) The role of infiltration in nonlinear watershed analysis processes. Transactions, ASAE, Volume 10, Number 3. Pages 396-399, 404. (B-005-CAL)

1967. (b) The nonlinear prediction problem in the study of the runoff cycle. Water Resources Research, Volume 3, Number 3. Pages 861-880. (B-005-CAL)

Amorocho, J., Albin Brandstetter, and Donald Morgan
1967. The effects of density of recording rain gauge networks on the description of precipitation patterns. Proceedings, IASH, General Assembly, Bern, Switzerland, September - October 1967. (B-005-CAL)

Bargur, J. S.
1969. Economic evaluation of water-Part VI: A dynamic interregional input-output programming model of the California and western states water economy. Water Resources Center Contribution Number 128. 125 pages. (B-017-CAL)

Davenport, D. C. and R. M. Hagan
1969. Antitranspirants. 1970 McGraw-Hill Yearbook of Science and Technology. In press. (B-054-CAL)

Davenport, D. C., R. M. Hagan, and P. E. Martin
1969. Antitranspirants research and its possible application in hydrology. Water Resources Research. In press. (B-054-CAL)

Dracup, John A. and Yacov Y. Haimes
1968. On multilevel optimization in ground-water systems. Proceedings, National Symposium on the Analysis of Water Resource Systems: American Water Resources Association, Denver, Colorado. (A-033-CAL)

Dracup, John A., Y. Y. Haimes, and R. L. Perrine
1968. Identification of distributed unconfined aquifer parameters. Proceedings, Fourth American Water Resources Conference, New York City. (A-033-CAL)

Fischer, R. A.
1968. Stomatal opening in isolated epidermal strips of *Vicia faba*: I. Response to light and to CO_2-free air. Plant Physiology, Volume 43. Pages 1947-1952. (B-029-CAL)

Fischer, R. A. and T. C. Hsiao
1968. Stomatal opening in isolated epidermal strips of *Vicia faba*: II. Responses to KCl concentration and the role of potassium absorption. Plant Physiology, Volume 43. Pages 1953-1958. (B-029-CAL)

Hall, W. A., A. J. Askew, and W. W-G. Yeh
1969. Use of the critical period in reservoir analysis. Fiftieth Annual Meeting, American Geophysical Union, Washington, D.C. Water Resources Research. In press. (B-061-CAL)

Hall, W. A., G. W. Tauxe, and W. W-G. Yeh
1969. An alternate procedure for the optimization of operations for planning with multiple-river, multiple-purpose systems. Water Resources Research. In press. (B-061-CAL)

Javandel, I. and P. A. Witherspoon
1968. Application de la méthode des éléments finis aux écoulements transitoires en milieu poreau. Revue de L'Institut Francais du Pétrole et Annales des Combustibles Liquides, Volume XXIII, Number 12. (B-066-CAL)

Larock, Bruce
1969. Gravity - affected flow from planar sluice gates. Journal of the Hydraulics Division, Proceedings ASCE, Volume 95, Number HY4. 100 pages. (B-037-CAL)

Lofting, Everard M. and H. Craig
1968. The interindustry factor-content matrix: applications on a multiregional basis. Publication of Sanitary Engineering Research Laboratory, University of California, Berkeley, Volume 4, Number 4. Pages 689-695. (B-017-CAL)

Lofting, E. M. and P. H. McGauhey
1968. Economic evaluation of water - Part IV: an input-output and linear programming analysis of California water requirements. Water Resources Center Contribution Number 16. 187 pages. (B-017-CAL)

Shapiro, David L.
1968. The Sacramento Diverters controversy, a study in the legal adjustment of externalities. Western Economic Journal, Volume 6, Number 4. Page 331. (B-065-CAL)

Shapiro, David L. and Jack Hirshleifer
1969. The treatment of risk and uncertainty. Report, The Analysis and Evaluation of Public Expenditures: The PPB System, Joint Economic Committee, Subcommittee on Economy in Government, Volume 1. Pages 505-530. (B-065-CAL)

Strelkoff, Theodor
1969. (a) One-dimensional equation of open-channel flow. Journal of the Hydraulics Division, Proceedings, ASCE, Volume 95, Number HY3, Paper 6557. (B-037-CAL)

1969. (b) Numerical solution of the Saint Venant equations. Journal of the Hydraulics Division, Proceedings, ASCE. In press. (B-037-CAL)

Vermuri, V. and J. A. Dracup
1967. Analysis of nonlinearities in ground-water hydraulics: a hybrid computer approach. Water Resources Research, Volume 3. Pages 1047-1058. (A-032-CAL)

Vemuri, V. and W. J. Karplus
1969. Identification of nonlinear parameters of ground-water computations by hybrid computation. Water Resources Research, Volume 5. Pages 172-185. (A-032-CAL)

Dissertations and Theses

Acevedo, E.
1969. Rapid response of elongation of leaves of *Zea mays* to changes in their water status. M.S. thesis. University of California, Davis. 95 pages. (B-029-CAL)

Brandstetter, Albin
1966. Parametric characterization of storms. M.S. thesis. University of California, Davis. 85 pages. (B-005-CAL)

Espildora-Couso, Basilio
1965. Synthesis of snow melting processes. M.S. thesis. University of California, Davis. 156 pages. (B-005-CAL)

Guymon, Gary L.
1967. A simple cascade watershed model. M.S. thesis. University of California, Davis. 163 pages. (B-005-CAL)

Harboe, Ricardo C.
1968. Optimum firm power output from a single-reservoir system by dynamic programming. M.S. thesis. University of California, Los Angeles. 52 pages. (B-061-CAL)

Humble, G. D.
1969. The role of potassium and other inorganic ions in stomatal movement. Ph.D. dissertation, University of California, Davis. 122 pages. (B-029-CAL)

Humble, G. D. and T. C. Hsiao
1969. Specific requirement of potassium for light-activated opening of stomata in epidermal strips. Plant Physiology, Volume 44. Pages 230-234. (B-029-CAL)

Javandel, Iraj
1968 Analysis of transient fluid flow in multi-layered systems. University of California, Berkeley. Ph.D. dissertation. 119 pages. (B-066- CAL)

Sakkas, John
1968. Water-surface profiles in rectangular channels with concentrated partial outflow through a bottom slot. M.S. thesis. University of California, Davis. 139 pages. (B-037-CAL)

Terzidis, George
1968. Discontinuous unsteady flow in open channels. Ph.D. dissertation. University of California, Davis. 105 pages. (B-037-CAL)

Travis, R. L., W. R. Jordan, and R. C. Huffaker
1969. Evidence for an inactivating system of nitrate reductase in Hordeum vulgare L. during darkness that requires protein synthesis. Plant Physiology. In press. (B-029-CAL)

Vemuri, V.
1968. Identification of nonlinear parameters in distributed systems: a hybrid computer approach. Ph.D. dissertation. University of California, Los Angeles. 207 pages. (A-032-CAL)

COLORADO

Publications

Aase, J. K., and W. D. Kemper.
1968. Effect of ground color and microwatershed on corn growth. Journal, Soil and Water Conservation. 23:60-62. (A-002-COLO)

Aase, J. K., W. D. Kemper, and R. E. Danielson.
1968. Response of corn to white and black ground covers. Agronomy Journal. 60:234-236. (A-002-COLO)

DiSilvio, G.
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APPENDIX R

OFFICE OF WATER RESOURCES RESEARCH

COLLEGES AND UNIVERSITIES AFFILIATED WITH THE STATE WATER RESOURCES RESEARCH INSTITUTES IN THE TITLE I PROGRAM - FISCAL YEAR 1969

University of Alabama
Alaska Methodist University, Anchorage
Arizona State University
University of California, Berkeley
University of California, Davis
University of California, Riverside
University of Colorado, Boulder
Florida State University
University of Georgia
Southern Illinois University
University of Iowa
University of Kansas
University of Louisville, Kentucky
Louisiana Polytechnic Institute
Louisiana State University
University of Maine
Smith College, Massachusetts
Springfield College, Massachusetts
University of Michigan
University of Southern Mississippi
University of Missouri, Rolla
University of Missouri, St. Louis
University of Montana, Missoula
Montana Collage of Mineral Science and Technology
St. Anselms College, New Hampshire
Stevens Institute of Technology, New Jersey
University of New Mexico
State University of New York
University of North Carolina, Chapel Hill
University of North Carolina, Moorehead City
Duke University, North Carolina
University of North Dakota
University of Oklahoma, Norman
South Dakota School of Mining and Technology
University of South Dakota
Vanderbilt University, Tennessee
Texas Technological College
University of Texas
University of Houston, Texas
University of Virginia
University of Richmond
University of Washington, Seattle
Marquette University, Wisconsin
University of Wisconsin, Greenbay
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